PROJECT TITLE:	**Cryogenic Dielectrics R&D for Electric Power Applications**
ORGANIZATION:	**Oak Ridge National Laboratory**
PRESENTERS:	I. Sauers
FY 2006 FUNDING:	$200K (DOE to ORNL)

Project Purpose and FY 2006 Objectives: Cryogenic dielectrics, like cryogenic cooling systems, is an enabling technology for high temperature superconducting (HTS) grid applications. The project objective is to develop and characterize cryogenic dielectric materials for use in HTS grid applications. In general work is required in two areas: materials R&D and conservative design techniques. The number of available materials that can provide high voltage electrical insulation in typical thermal gradients from 300 to 30-80 K and mechanically compatible with typical conductors and structural materials is not large. Materials currently used include some epoxies, G-10/11, cable tapes, Ultem™ and vacuum. Vacuum as an electrical insulation medium is not reliable and subject to the Paschen breakdown as it degrades due to external leaks and outgassing. Even these materials are not completely characterized. There are typically little data on partial discharge and impulse (lightning) performance as most prior low temperature superconducting applications have been dc. Significant partial discharge will eventually produce a breakdown in ac applications. More fully-characterized, cryogenic dielectric materials are needed to allow designers to make engineering tradeoffs in real devices. Proven techniques need to be developed to allow designers to integrate these materials in a reasonable and robust insulation package that can meet stringent IEEE requirements (ac withstand, partial discharge, BIL and surge transients) and function at operating voltage for 20-40 years (~10^{11} cycles). A common feature in many of the HTS SPI projects is the requirement for reliable high voltage electrical insulation. Failures in a few cases have underscored the need for improved dielectric materials and a better understanding of the high voltage issues. Work to date has indicated that what is learned in one project can often benefit other projects but proprietary issues can limit access. Hence a strategic program on cryogenic insulation has been initiated which will address the material needs which are common to all the projects and provide a data base of knowledge which will facilitate the design of various cryogenic insulation systems.

FY 2006 Performance and FY 2007 Plans: Due to significantly reduced funding levels from what was proposed in the FY 2006 performance plans presented at the 2005 DOE Peer Review, R&D activities were scaled back, but progress has been made in a number of areas. These include a successfully completed Cryogenics Dielectrics Workshop, the development of new cryogenic dielectrics materials based on nanocomposite technology and the measurement of dielectric properties of some commonly used materials in existing SPI projects.

FY2007 plans will involve a continuation of the work in new materials and in the measurement of dielectric properties of existing materials. Data will be compiled into a spreadsheet which can be made available to SPI participants. Other activities such as the development of a web site and the inclusion of industry, universities and other labs would depend on the funding levels for FY2007.

FY 2006 Results: A summary of the accomplishments include:

1. Cryogenic Dielectrics Workshop: A 1-day workshop on cryogenic dielectrics was held on October 16, 2005 in Nashville, Tennessee, in conjunction with the Conference on Electrical Insulation and Dielectric Phenomena (CEIDP). The workshop was partially supported by the IEEE

Dielectrics and Electrical Insulation Society and the IEA working group on Superconductivity. There were ten invited presentations covering subjects on various aspects of cryogenic dielectrics for superconducting applications. Approximately 50 scientists and engineers from industry and utilities attended. The workshop was documented with a hard copy and a CD of the presentations.

2. New dielectric materials: Composite dielectrics are needed for applications requiring either mechanical strength, thermal conductivity, thermal compatibility, or matching permittivity, etc., in addition to the basic requirement of high dielectric strength. In general the filler in composites tend to lower the dielectric strength from that of the unfilled dielectric material. We have developed new materials based on nanocomposites which have higher dielectric strength than the unfilled polymer. A novel technique will be described for making well dispersed nano fillers “in situ” and dielectric strength data will be presented.

3. Statistics of breakdown: Weibull statistics are often used in analyzing breakdown data for solid materials. Convergence in the determination of the Weibull parameters is often difficult to assess, especially when the sample size is small. Other statistical methods have been explored revealing improved methods for analyzing breakdown data.

4. Breakdown data on Cryoflex, Kapton, and G10: Breakdown data on Cryoflex, Kapton and G10 have been measured at liquid nitrogen temperatures and at room temperature. These data will be reported.

5. Polarization/relaxation: Other dielectrics properties such as polarization and relaxation have been measured using a new experimental facility. These data provide insight into the nature of space charge accumulation in dielectric materials and resulting partial discharge and electrical breakdown.

6. Complex permittivity as function of frequency and temperature: An impedance spectrometer has been coupled to a cryogenic refrigerator to permit the measurement of the complex permittivity as a function of temperature and frequency. Thus permittivity and dissipation losses can be measured from room temperature down to around 30 K. Initial data will be presented.

Research Integration: The driving force for strategic cryogenic dielectrics work is the development of HTS power equipment that can operate at high voltage on the grid reliably for design lifetimes. This involves significant collaboration with SPI teams, utilities and other labs. Work with SPI partners in the HTS cable, transformer, fault current limiter and generator projects have provided some generic data already. Conversely dielectric data on existing materials are expected to benefit future HTS projects in high voltage grid applications.