Organization:	**Oak Ridge National Laboratory**
Project Title:	**Cryogenic Dielectrics Research for Electric Power**
Presenter(s):	I. Sauers
FY 2005 Funding:	$100K

Project Purpose and FY 2005 Objectives:

The project objective is to develop and characterize cryogenic dielectric materials for use in HTS applications. A common feature in each HTS project is the requirement for reliable high voltage electrical insulation. Failures in a few cases have emphasized 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 the other projects but proprietary issues can limit access. Hence, a strategic program on cryogenic insulation is 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 varied insulation systems. The primary objective in FY 2005 has been to support the transformer, cable, generator, and fault current limiter projects. Generally specific insulation systems, components, and designs have been tested and validated for each project including scaling in solid dielectric, flashover in liquid nitrogen, and partial discharge (PD) in tape insulation.

FY 2005 Performance and FY 2006 Plans:

Summary of FY 2005 (and prior years) performance: A summary of the accomplishments include:

1) Breakdown strengths for filled epoxies were measured at 77 K for uniform and non-uniform electric field electrode geometries for different volumes and gaps.
2) Partial discharge characteristics of voids in solid insulation were measured at 295 K and 77 K for understanding of degradation mechanism and diagnosis of problems.
3) Extensive studies were performed on model cables using Cryoflex insulation for impulse and ac breakdown strength and lifetime aging characteristics.
4) Insulation materials and termination designs for cables were tested for ac withstand and impulse (BIL).
5) Partial discharge and aging studies were conducted on turn-to-turn insulation for HTS tapes at room temperature and 77 K.
6) Impulse and ac breakdown voltages for gaseous and liquid nitrogen under various practical geometries were measured to determine design rules for 138 kV class applications.

FY 2006 Plans:

1) A Cryogenic Dielectrics Workshop is being planned for October 16-17, 2005, in conjunction with the IEEE Conference on Electrical Insulation and Dielectric Phenomena to be held in Nashville, TN.

2) Proposed Strategic Cryogenic Dielectrics Initiative: Proposed work falls into two broad categories, (1) high voltage testing and characterization of currently available materials and (2) the development of new materials, specifically designed for cryogenic HTS applications. Specific tasks include the following:

   a) Development of new or alternative solid dielectric materials that have improved electrical and mechanical properties at cryogenic temperatures. Desirable properties include high dielectric strength, low losses, resistance to partial discharge, low thermal contraction and resistance to cracking, and high mechanical strength. Materials are also needed which have high dielectric strength and high thermal conductivity. Nanoparticle-filled composite materials have the potential to combine good mechanical and thermal properties without sacrificing dielectric strength over certain ranges.

b) Investigate the scaling properties of commonly used materials such as FRP (fiberglass reinforced plastic, G-10 e.g.) and liquid nitrogen. Work is needed to characterize and develop design rules for insulation strength as a function of volume and gap at cryogenic temperatures for a number of generic materials for both uniform and nonuniform fields.
c) Surface flashover voltages of FRP and other materials in gaseous and liquid nitrogen, and vacuum at cryogenic temperature are needed as a function of gap for different electrode triple junction geometries. Criteria for designing the triple junction to prevent initiation should be developed into design rules.
d) Lifetime and aging studies at cryogenic temperature of selected dielectric materials are needed to ensure reliable operation over a long period of time. Partial discharge in voids, delaminations, sharp edges, interfaces, or other defects can result in reduced lifetimes.
e) A more complete data base of cryogenic insulation needs to be developed and consolidated. This data would be highly useful for all designers of high voltage equipment. Results would be made available on a web site.
f) Diagnostic techniques for determining fault location, impending faults, hot spots, bubble formation, condition monitoring, etc., are an important area if the HTS devices are to be accepted as commercial products.

FY 2005 (and previous years) Results:

1) Breakdown strengths of epoxy materials have been measured for filled and unfilled materials. Filled epoxies such as Stycast were found to survive severe thermal shock tests and provide adequate insulation strength in small samples, but with decreasing dielectric strength in larger samples. Additionally it was found that voids can be formed as a result of the curing process in large volumes which result in partial discharge at relatively low voltage and early failure.
2) Aging studies were performed on two different sizes of model cable using a lapped polymer tape insulation. Cables were aged at different constant electric fields at 77 K in a cryostat until failure occurred.
3) Aging and PD tests were conducted on turn-to-turn (or edge-to-edge) insulation on HTS tapes with several different types of insulating material. PD was found to occur in small voids in the edge-to-edge region between tapes if there is no potting material present. PD was measured as a function of temperature from 295 K to near 40 K.
4) Impulse and ac breakdown studies were performed in liquid and cold gaseous nitrogen on a variety of electrode configurations, gaps, and pressures such as sphere-plane, rod-plane, and cylindrical. Surface flashover studies were also conducted with different geometries. Scaling issues in going to larger gaps were investigated.

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. An industry advisory panel will be formed to provide review and feedback on R&D needs for this initiative.