Organization:	Oak Ridge and Los Alamos National Laboratories
Project Title:	**Design and Development of a 100 MVA HTS Generator**
Presenters:	Jim Fogarty (GE), Robert Duckworth (ORNL), Eric Schmierer (LANL)
FY 2005 Funding:	$ 206 K (ORNL), $ 430 K (LANL)

Project Purpose and FY 2005 Objectives: General Electric's Global Research in Niskayuna, N.Y., will design and develop a 100 MVA class high temperature superconducting generator, with designs through 250 MVA. The HTS rotor will be capable of retrofitting into existing generators. ORNL and LANL have entered into CRADAs with GE to provide assistance in several technology areas.

For FY 2005 ORNL will:

- complete measurements of total hemispherical emissivity of specified surfaces at temperatures between 30 K and 40 K, with and without controlled surface contamination;
- measurement of transient tape resistances at different over-current and applied dc fields; measure turn-ac PDIV as a function of temperature for composite samples with voids;
- assist GE with design and testing of the HTS coil quench protection system.

For FY 2005 LANL will:

- submit final reports on room temperature HTSG material outgassing for measurements performed and on new samples as needed
- assemble apparatus to test rotating heat pipe, acquired data and compare to detailed model
- fabricate hardware and modify apparatus to test closed loop, passively pumped cooling experiment, acquire data and compare to model
- complete measurements of AC loss and over current situations and compare to model predictions
- assess impact of 2nd generation HTS conductor on generator design

FY 2005 Performance/FY 2006 Plans:

For FY 2005, ORNL measured the emissivity of additional, silver-plated, copper shield samples with different room temperature emissivities at 30 K. Evaluated emissivity degradation of surfaces with respect to direct water contamination and contamination that resulted from outgassing of candidate structural rotor materials. Examined partial discharge in trapped air-filled gaps at temperature between 295 K and 41 K. With respect to quench detection and protection, ORNL staff participated in a design review of the quench detection system for the 100 MVA rotor coil and worked with staff at GE Global Research on a series of quench experiments that were conducted on a prototype HTS coil.

ORNL Plans for FY 2006

1. Pulsed aging studies on test samples and coils for validating proprietary, modified insulation system.
2. Assist GE with design and testing of the HTS coil quench protection system on prototype and full scale coils.

For FY 2005, LANL completed outgassing measurements and experiment preparation for rotating heat pipe and determined reliable heat pipe assembly procedure. Performed studies of ac losses/overcurrents and assessed impact of 2nd generation conductor on generators.

LANL Plans for FY 2006

1. Complete rotating heat pipe experiment testing and comparison to modified model.
2. Perform closed loop passively cooled loop testing and comparison to model.
3. Assist GE with reverse Brayton cycle development.
4. Assist in ac loss studies of HTS generator coils and 2nd Gen HTS impact on future generator designs

FY 2005 Results:

Significant progress has been made at ORNL during the year.

Emissivity Degradation: The increase in emissivity of silver-plated copper plate samples at 30 K due to direct water contamination was characterized. It was found that samples with low emissivity at room temperature have lower emissivity at 30 K, but the emissivity degradation due to direct water

contamination was similar in all samples. When water was introduced through materials with known water vapor out-gassing, the degradation of the emissivity was also characterized.
Dielectric testing: Partial discharge (PD) in trapped air-filled gaps between two adjacent insulated high temperature superconducting (HTS) tapes made of BSCCO was investigated experimentally. PD measurements were performed at several temperatures ranging from 295 K to 41 K. At each temperature a series of AC voltages of equal duration and increasing magnitude were applied to the inter-turn insulation until PD was initiated and observed on the insulation condition monitor ICM digital PD system. The PD data are presented in the form of phase and amplitude resolved PD patterns. Experimentally obtained PD inception and extinction voltages were compared with the Paschen curve values for air and the effect of temperature on PD inception was discussed. The data show that relatively low PD onsets can occur even when the insulation is cooled to the 40 to 50 K range which may be due to the presence of ice layers on the surface of the voids.
Quench Detection and Protection: After participating in a design review for the quench detection system of the 100 MVA generator coil, ORNL staff worked together with GE staff to test a 1.5 MVA-size demonstrator coil to determine the feasibility of different quench detection and protection schemes. Quenches were initiated in the coil, which was cooled with helium to 36 K, by increasing the coil current above the critical current and the voltage and temperatures within the coil were measured.
LANL conducted several valuable studies during the past review period.
Outgassing of Materials: The third outgassing report was completed summarizing true outgassing rates of Rulon and Ultem to compare to G10. Given the uncertainties in the measurements and variations between samples, the differences in these values were not significant. True outgassing rate of a carbon fiber reinforced sheet material that was being considered for use in the rotor of the HTS generator. Results for G-10 samples alternatively kept in a 100 % humidity environment for 3 weeks, baked out at 150 C for 24 hrs, humidified again, then a final bake out at 150 F for 24 hrs were determined. Calibration of the bakeout furnace temperature measurement was performed to determine previous sample bakeout temperature.
Rotating Heat Pipe Development: Modifications to the full Navier-Stokes heat pipe model were completed per comments from various internal and external reviews. The rotating heat pipe experiment went through thorough assessment of the operating hazards. Analysis of the projectile shielding and design is complete and the shielding has been fabricated. A transient test of the condenser coolant bath was performed and was satisfactory. Several straight heat pipe wick structure designs and fabrication methods were tested. The final heat pipe configuration and a reliable fabrication method have been determined.
Closed, Passively Cooled Loop Testing: The fixturing and tooling for this test have been designed and testing awaits completion of the heat pipe portion of the test plan.
AC Loss/over current testing: ac losses: The ac loss/overcurrent apparatus was assembled and measurements and modeling conducted..
2nd Generation HTS Conductor Impact: Initial studies were conducted of the impact of HTS coated conductors on future generators with substantial potential improvements in performance and lowering of costs.

Research Integration: ORNL and LANL have teleconferences with GE staff to ensure that R&D objectives, efforts, and results are in accord with project objectives. The results are reviewed by GE staff. ORNL presented papers on the high voltage tape insulation test configuration and results from generic insulation materials at the 2004 *Applied Superconductivity Conference* and the 2004 IEEE *Conference on Electrical Insulation and Dielectric Phenomena*. A paper will be presented at the *2005 CEC/ICMC* on the final emissivity degradation results involving the direct water contamination and its relation to water from out-gassed materials. LANL exchanged samples for outgassing measurements, and exchanged software models for rotor alternative cooling methods. Continued interactions with Prof. Razani of University of New Mexico on heat pipe. LANL student Todd Jankowski submitted PhD thesis to committee based on these studies.