Project Title:	Design and Development of a 100 MVA HTS Generator
Organization(s):	**Oak Ridge and Los Alamos National Laboratories**
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FY 2004 Funding:	$325 K (ORNL), $330 K (LANL)

Project Purpose and FY 2004 Objectives: General Electric's Global Research in Niskayuna, N.Y., will design and develop a 100 MVA class high-temperature superconducting (HTS) 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 2004 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; measure transient behavior of short conductor samples in support of modeling of the HTS rotor coil; measure turn-to-turn impulse breakdown strength of candidate insulation materials at 77/300 K; perform accelerated pulsed aging tests on the selected insulation at 77/300 K; measure partial discharge initiation voltage (PDIV) for composite samples at 77/300 K.

For FY 2004 LANL will: continue characterizing the room temperature outgassing properties of materials supplied by GE; evaluate the impact of low temperature bakeout of composite materials on outgassing; provide list of possible getter materials; provide prescription for long-term vacuum maintenance; enhance thermal model for rotating heat pipe cooling and assemble experimental apparatus to verify model predictions; develop thermal model for passively pumped single-phase helium cooling loop; and model and measure thermal impact of over-currents in GE-provided HTS coil to predict temperature rise in rotor coil during over-current faults.

FY 2004 Performance/FY 2005 Plans: For FY 2004, ORNL measured the emissivity of silver-plated copper shield samples and hand-polished copper shield samples at 30 K. Evaluated emissivity degradation of surfaces with respect to air and water contamination. Conducted preliminary measurements of outgassing of rotor material and its impact on emissivity. Completed modifications to an existing apparatus and conducted preliminary measurements to characterize the transition of HTS conductors down to 30 K and in dc fields up to 4 T. Conducted measurements of turn-to-turn impulse breakdown dielectric strength for two candidate types of superconducting wire insulation at ambient and liquid nitrogen temperatures and completed PDIV measurements and accelerated pulsed aging tests on the candidate insulation at ambient temperature, and initiated experiments at liquid nitrogen temperature.

For FY 2004, LANL has developed an outgassing model incorporating readsorption; measured outgassing properties of 11 different materials requiring over 90 outgassing experiments; modeled and measured the impact of vacuum bakeout temperature and duration on outgassing of fiberglass composites; published a paper presenting the prescription for long-term vacuum maintenance; developed a complete thermal model of heat pipe performance as a function of rotation rate; designed and fabricated all the parts for a room temperature, rotating heat pipe apparatus to verify thermal model predictions; apparatus is partially assembled awaiting final heat pipe; developed a heat pipe wick that could maintain shape integrity through bending of the heat pipe; assembled and tested full-scale straight and bent heat pipes; assembled test rig with cryocooler and HTS coil from GE for measuring temperature rise during over-current fault.

ORNL Plans for FY 2005

1) Complete measurements of the total hemispherical emissivity of specified surfaces at temperatures between 20-40 K including surface contamination, whether it originates from a direct leak or outgassing of rotor materials placed in the vacuum space. Submit final report.
2) Complete measurement of transient composite tape resistances at different over-currents and applied dc fields up to 4 T. Submit final report.

3) Measure ac PDIV as a function of temperature for composite samples with voids. Submit final report.
4) Assist GE with design and testing of the HTS coil quench protection system.

LANL Plans for FY 2005

1) Extend CRADA with GE.
2) Continue outgassing and bakeout measurements as needed by GE and provide summary reports.
3) Complete rotating heat pipe experiments, update model as required. Submit final report.
4) Modify rotating heat pipe apparatus for passively pumped cooling loop. Complete passively pumped cooling loop experiments and compare to thermal model predictions. Submit final report.
5) Complete analysis of impact of 2nd generation HTS conductor on GE rotor. Submit final report.

FY 2004 Results:

Significant progress has been made at ORNL during the year.

Emissivity test rig - Emissivities have been measured for silver-plated and bare copper shield samples between 25 K and 35 K. The impact of water and air contamination on emissivity has been completed for silver-plated copper samples and a follow-on study was conducted to correlate water contamination from leaks and materials in the rotor vacuum insulation that could impact the total refrigeration heat load.

Dielectric testing - Measurements of the turn-to-turn dielectric strength with respect to the impulse breakdown voltage were completed for two candidate types of superconducting wire insulation at ambient and liquid nitrogen temperatures. Accelerated pulsed aging tests and PDIV measurements on the selected wire insulation system were completed at ambient temperature and initiated at liquid nitrogen temperature. At ambient temperature the slope of the lifetime aging curve was found to decrease at a lower voltage which indicates a change in the aging mechanism(s). Further work will determine if different aging mechanisms are also found for the case of cryogenic temperatures and whether the rate of aging will decrease significantly when the tape samples are cooled to liquid nitrogen temperature.

Significant progress has been made at LANL during the year.

Outgassing and bakeout measurements - Models have been developed to facilitate understanding of performance; 11 different materials have been characterized, requiring over 90 different experiments.

Heat pipe and passive cooling loop - A detailed thermal model has been developed for both the heat pipe and the passively cooled single-phase helium loop; a room temperature experiment has been designed and fabricated. Assembly is awaiting the full scale heat pipe. A wick structure has been developed to maintain the geometric integrity of the wick after the heat pipe has been bent into the crank shape; straight and bent heat pipes have been assembled and tested.

HTS coil over-current measurement - HTS coil from GE has been instrumented and mounted in contact with a cryocooler. Preliminary measurements of temperature rise versus over-current have been made.

Research Integration: ORNL and LANL have regular 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. One technical poster on the emissivity measurements was presented at the *Cryogenic Engineering Conference* in September 2003. In addition, the exchange of information between ORNL and LANL has led to productive discussions with GE on the role of materials in the rotor vacuum space. ORNL will present papers on the high voltage tape insulation test configuration and results from generic insulation materials at the 2004 *Applied Superconductivity Conference* and the 2004 *Conference on Electrical Insulation and Dielectric Phenomena*. LANL has published the long-term vacuum maintenance prescription in *Advances in Cryogenic Engineering* and the details of the thermal model of the rotating heat pipe model will be presented at the 2004 ASME *Heat Transfer/Fluids Engineering Summer Conference.*