Project Title:	**Development of Ultra-Efficient HTS Motor Systems**
Organization(s):	**Rockwell Automation**
Presenters:	Rich Schiferl
FY 2004 Funding:	$750 K

Project Purpose and FY 2004 Objectives: The purpose of the project is to perform research in eight areas related to commercial viability of industrial motors with high temperature superconducting (HTS) windings. The eight areas were identified based upon the past work that Rockwell Automation had conducted on development and testing of HTS based motors up to and including the laboratory test of a 1600 hp motor. These research areas and objectives are listed below. Since this is the first year of reporting on this project, the overall project objectives are listed below.

Research Area	Overall Objective
1. Alternate HTS motor topologies	Investigate designs and verify with test a superconducting induction motor concept and a combination superconducting and permanent magnet motor concept.
2. Alternate HTS wire technology applications	Acquire second generation conductor and coil samples and perform tests to simulate motor requirements.
3. Eddy current heating in air-core, rotating machinery	Complete simulation model and verify with test rig to reduce losses in end regions.
4. Adjustable speed drive integration / harmonic shielding for HTS motors	Complete simulation models and verify with comparison to HTS motor test data.
5. On-board refrigeration system development	Conduct research to verify viability of on-board cryogenic system (on the rotor).
6. Coil quench protection system development	Analyze quench event from 1000 hp motor and develop reliable quench monitoring and protection system for HTS motors.
7. Composite torque tube advancement	Investigate the creep and fatigue phenomena associated with composite torque tubes in large scale HTS motors.
8. Cryogenic persistent switch investigation for HTS field windings	Verify feasibility of using cryogenic persistent switch in HTS motors.

FY 2004 Performance, FY04 Results and FY 2005 Plans by research area: Progress has been made in each of the research areas identified above. Below is a summary of the results and next year's plans.

1. Alternate HTS motor topologies

FY04 Performance	FY04 Results	FY05 Plans
• Evaluated superconducting induction motor (SCIM) literature and potential options for open circuiting an HTS film.	• Initial model and thin film construction results showed SCIM construction will be problematic.	• Investigate alternate methods to open circuit HTS coils or films. Issue report on studies and tests.
• Literature search on permanent magnet (PM) performance at cryogenic temperatures.	• Some exotic PM materials retain performance at cryogenic temperatures. Tests on a common material showed 20% reduction in flux at cryogenic temperatures.	• Perform design study trade-off for PM vs HTS content and issue report.

2. Alternate HTS wire technology applications

FY04 Performance	FY04 Results	FY05 Plans
• Provided wire and coil performance specifications for small HTS motor to 2nd gen wire vendor.	• Initial design of small HTS motor using 2nd Gen coils	• Build and test 2nd Gen HTS coil for motor application studies.

3. Eddy current heating in air-core, rotating machinery

FY04 Performance	FY04 Results	FY05 Plans
• Completed modeling of end region. Built test rig and verified performance with tests.	• Tests and models showed increased loss is a strong function of the location of the HTS field poles with respect to the end of the stator core.	• Complete report on tests and model verification.

4. Adjustable speed drive integration/harmonic shielding for HTS motors

FY04 Performance	FY04 Results	FY05 Plans
• Developed simulation model of HTS motor with medium voltage drive.	• Simulation completed and results compared to HTS motor test data.	• Verify simulation model with controlled test of HTS/motor and drive system.

5. On-board refrigeration system development

FY04 Performance	FY04 Results	FY05 Plans
• Evaluated cryocooler options and selected model for test rig.	• Purchase order placed for pulse tube refrigerator. CRADA with NIST under negotiation	• Complete system model with CRADA work. Build and test rotating cryocooler system.

6. Coil quench protection system development

FY04 Performance	FY04 Results	FY05 Plans
• Evaluate quench event and investigate quench prevention / protection options	• Quench event data reviewed and report written.	• Quench model development and choose best prevention option. Demonstrate solution and perform rotating exciter tests.

7. Composite torque tube advancement

FY04 Performance	FY04 Results	FY05 Plans
• Develop creep test method.	• Creep test rig designed and built for single sample. Tests initiated.	• Complete creep tests on multiple samples. Issue report on fatigue test needs.

8. Cryogenic persistent switch investigation for HTS field windings

FY04 Performance	FY04 Results	FY05 Plans
• Review switch options and characterize performance at cryogenic temperature.	• Electronic switch selected and some preliminary test data obtained.	• Complete test of persistent switch with HTS coil to prove performance.

Research Integration: Modeling of the performance of a pulse tube refrigerator in a high-g environment will be conducted through a CRADA agreement between Rockwell Automation and NIST. Modeling results will be compared to test data.