ORNL/HTSPC-1

OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA

Survey of Domestic Research on Superconducting Magnetic Energy Storage

L. Dresner

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

ORNL/HTSPC--1

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High-Temperature Superconductivity Pilot Center

SURVEY OF DOMESTIC RESEARCH ON SUPERCONDUCTING MAGNETIC ENERGY STORAGE

L. Dresner

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INTRODUCTION

This report documents the results of a survey of domestic research on superconducting magnetic energy storage (SMES) undertaken with the support of the Oak Ridge National Laboratory (ORNL) Superconductivity Pilot Center for the benefit of the Office of Energy Management, Office of Utilities Technology, of the U.S. Department of Energy (DOE). The survey budget was $25,000.

Each survey entry includes the following:

- Name, address, and telephone and facsimile numbers of the principal investigator and other staff members.
- Funding for fiscal year (FY) 1991, 1992, and 1993.
- Brief descriptions of
  - — the program,
  - — the technical progress to date, and
  - — the expected technical progress.
- A note on any other collaboration.

Included with the survey are recommendations intended to help DOE decide how best to support SMES research and development (R&D).

The survey is based on letters of inquiry sent to persons (i) known to me from my work on the technical advisory group (TAG) of the Defense Nuclear Agency/Electric Power Research Institute (DNA/EPRI) SMES Engineering Test Module (ETM) study, (ii) recommended by respondents, (iii) discovered from a literature search that I undertook, (iv) encountered at SMES meetings, or (v) whose names appeared in the programs of superconductivity or cryogenics meetings. There was sufficient repetition among these different sources to convince me that I have discovered all important SMES research currently under way in the United States.

The major SMES program of the last two years has been the DNA/EPRI SMES-ETM program. At the time of writing, this program is being terminated. There appears to be some Congressional support for continuing it, but it is too early to tell what the eventual outcome will be.

In addition to this major program, several smaller programs are under way or have recently been completed. They involve

(i) SMES for electric networks (line stabilization, load leveling, reduction of spinning reserve, decrease in use of premium fuels),

(ii) SMES for rapid transit systems,

(iii) SMES as a noninterruptible or long-lived power supply,

(iv) SMES for the Army (replacing batteries or for the all-electric tank), and

(v) SMES as an enabling technology for solar and wind power production.

Items (i) and (v) are most closely related to the important task of supplying base-load electric power. Item (i) relates to the cost of electric power: it is believed that the cost reduction resulting from load leveling will outweigh the cost of the SMES itself, leading to net savings. To assess the cost of SMES accurately and possibly to reduce it by improved design will require construction and operating experience that can only be acquired by building and operating a SMES unit. The DNA/EPRI ETM seemed ideal for this purpose.

Item (v) relates both to cost (since solar and wind power have no fuel cost) and environmental safety (since solar and wind power emit no effluents). If an ETM were built and located at a site where solar or wind generation is possible, the impact of SMES as an enabling technology could be assessed.

A variety of other R&D benefits that could be derived from the DNA/EPRI ETM were discussed in a recent workshop entitled "Research Opportunities for the SMES-ETM," held at the Naval Postgraduate School in Monterey, Calif. (July 17–18, 1991). A report will soon be issued of the conclusions of the workshop, which may be of interest to readers of this survey.

The tasks of items (ii), (iii), and (iv) are much easier than those of items (i) and (v) because the SMES units of the former are much smaller than those of the latter. It is certainly easier and cheaper to begin with small-scale SMES. But, in my opinion, what will be learned from developing small-scale SMES will not always be useful in developing large-scale SMES because the problems at the two sizes are quite different. At the small size, the chief problems are those of voltage withstand and vapor clearance. At the large size, the chief problems are those of transmitting the Lorentz forces to the trench walls and maintaining enormous inventories of superfluid helium. Nevertheless, small-scale SMES has its uses and should be developed for its own sake.

Some of these problems will be mitigated by the use of high-temperature superconductors. Vapor production will be less in small-scale SMES, and maintaining the cryogen inventory will cease to be a problem in large-scale SMES. Others, like the structural problems of large-scale SMES, will be only slightly affected. (Structural considerations provide a good way to define small and large SMES: small units are those that can be supported by a free-standing structure; large units are those that must be supported by the walls of a trench in the ground.)

To summarize, I would say that important elements of a well-rounded SMES research program for DOE are as follows.

1. Construction of a large ETM.
2. Development of SMES as an enabling technology for solar and wind generation, especially in conjunction with the ETM program, if possible.
3. Development of small SMES units for electric networks, for rapid transit, and as noninterruptible power supplies [uses (ii), (iii), and (iv) above]. In this connection, lightweight, fiber-reinforced polymer structures, which would be especially advantageous for space and transportation applications, should be developed.
4. Continued study of the potential impacts of high-temperature superconductors on SMES, with construction as soon as feasible of small SMES units using high-temperature superconductors (HTSs).

CROSS-INDEX OF ORGANIZATIONS WITH PRINCIPAL INVESTIGATORS

The survey entries in the main part of this report are alphabetized according to the last name of the principal investigator. The first part of the following list cross-references the main organizations with the names of the principal investigators. The second part cross-references the collaborating organizations with the names of the principal investigators.

ORGANIZATION	PRINCIPAL INVESTIGATOR
Main organizations	
Bay Area Rapid Transit District	Nerenberg, Victoria
Bechtel National, Inc.	DNA/EPRI Study
David Taylor Research Center	DNA/EPRI Study
Defense Nuclear Agency	DNA/EPRI Study
Ebasco Services, Inc.	DNA/EPRI Study
Electric Power Research Institute	DNA/EPRI Study
Hydro-Quebec	Begin, Ghislain
Idaho National Engineering Laboratory	Herring, J. Stephen
LABCOM, Fort Monmouth	Guazzoni, Guido
Oak Ridge National Laboratory	Cohn, Steve M.
Oak Ridge National Laboratory	Dresner, Lawrence
Oak Ridge National Laboratory	Lue, J. Winston
Pacific Northwest Laboratory	De Steese, John G.
Solar Energy Research Institute	McConnell, Robert
Virginia Polytechnic Institute	Tam, Kwa-Sur
W. J. Schafer Associates	Schoenung, Susan
Collaborating organizations	
Advanced CryoMagnetics Inc.	Schoenung, Susan
Argonne National Laboratory	Guazzoni, Guido; Schoenung, Susan
Ball Aerospace	McConnell, Robert
Bonneville Power Administration	De Steese, John G.
CVI	DNA/EPRI Study
Chicago Bridge and Iron	DNA/EPRI Study
Colorado School of Mines	McConnell, Robert
Colorado State University	McConnell, Robert
Colorado Superconductor, Inc.	McConnell, Robert
Coors Ceramic Co.	McConnell, Robert
CWDC	DNA/EPRI Study

Gec Alsthom	Begin, Ghislain
General Atomics	DNA/EPRI Study; Schoenung, Susan
General Dynamics Corp.	DNA/EPRI Study
General Electric Corp.	DNA/EPRI Study
Kaman Scientific Corp.	Guazzoni, Guido; McConnell, Robert
Martin Marietta Corp.	McConnell, Robert
National Institute of Standards and Technology	DNA/EPRI Study; McConnell, Robert
Pacific Gas and Electric	Nerenberg, Victoria
Pitt-Des Moines Corp.	DNA/EPRI Study
Rocky Mountain Superconductivity Alliance	McConnell, Robert
Superconductive Technologies, Inc.	McConnell, Robert
Superconductivity, Inc.	Dresner, Lawrence; Nerenberg, Victoria
U.S. Air Force	McConnell, Robert
US West Advanced Technologies	McConnell, Robert
University of Colorado	McConnell, Robert
University of Wisconsin	DNA/EPRI Study
Westinghouse Electric Corp.	DNA/EPRI Study
Wright-Patterson Air Force Base	DNA/EPRI Study

SUMMARY OF SURVEY RESULTS

BEGIN, GHISLAIN—HYDRO-QUEBEC

IREQ, Hydro-Quebec Research Institute
1800 Montée Ste. Julie
Varennes, Quebec
Canada J3X 1S1

TITLE

SMES for the Electric Network

STAFF

Ghislain Begin, (514) 652-8317, FAX: (514) 652-8905
Momcilo Gavrilovic, (514) 652-8204, FAX: (514) 652-8180
Innocent Kamwa, (514) 652-8122, FAX: (514) 652-8005

FUNDING

FY 1991: $350,000
FY 1992: $3,000,000
FY 1993: $5,000,000

APPROACH; BRIEF DESCRIPTION OF PROGRAM

"Small SMES are considered as voltage and power regulation tools in order to improve the transient stability margin of Hydro Quebec transmission network. The approach is divided into 3 phases.

"1—A preliminary study that is aimed at making a technico-economical evaluation of SMES sized to the network expected needs (300 MVA, 0.1 MWh). A SMES is modelized and used in H. Q. numerical stability program to evaluate the impact of SMES on the planned 1996 transmission network. In addition, a cost estimate is being established in cooperation with Gec Alsthom, a potential industrial partner. This phase should be completed in '91.

"2—If the outcome of phase 1 is positive, a detailed design of a prototype 33 MJ, 10 MVA will be made [sic]. Preliminary tests on some components to insure the technical feasibility will also be done. This phase will extend in '92 and part of '93.

"3—Once technical feasibility will be proven in phase 2, the prototype will be built and tested as a demonstrator at Hydro Quebec high power laboratory. ('93–'94–'95)."

TECHNICAL PROGRESS TO DATE

None reported.

EXPECTED PROGRESS

See program description above.

OTHER COLLABORATION

Gec Alsthom

COHN, STEVE M.—OAK RIDGE NATIONAL LABORATORY
P.O. BOX 2008
Oak Ridge, TN 37831-6205

TITLE

SMES for Rapid Transit Applications

STAFF

Steve M. Cohn, (615) 574-5225
Ben W. McConnell, (615) 576-2733
D. Tom Rizy, (615) 574-5203

FUNDING

$60,000

APPROACH; BRIEF DESCRIPTION OF PROGRAM

The program was a study of the economic feasibility of integrating superconducting storage devices with rapid transit rail systems.

TECHNICAL PROGRESS TO DATE

A draft report with the title "Economic Feasibility of Integrating Superconducting Storage Devices with Rapid Transit Rail Systems" was issued on January 31, 1991. An earlier report issued on March 8, 1990, described the methodology ("Preliminary Framework for the Economic Feasibility of Integrating Superconducting Storage Devices with Rapid Transit Rail Systems").

EXPECTED PROGRESS

Program finished.

OTHER COLLABORATION

None reported.

DE STEESE, JOHN G.—PACIFIC NORTHWEST LABORATORY
P.O. Box 999, K5-02
Richland, WA 99352

TITLE

Electric Utility Benefits of Superconducting Magnetic Energy Storage [for Bonneville Power Administration (BPA), Portland, OR 97208]

STAFF

John G. De Steese, (509) 375-2057, FAX: (509) 375-3614
Jeffery E. Dagle, (509) 375-3629, FAX: (509) 375-3614
[Study commissioned by Walter Myers, R&D Manager at BPA, (503) 230-4009]

FUNDING

FY 1991: $50,000
FY 1992: TBD

APPROACH; BRIEF DESCRIPTION OF PROGRAM

"This study quantifies and compares SMES benefits and costs in potential application scenarios that could enhance electric utility operations in the BPA service area. The effort includes (1) the collection, development, and application of data and computational tools to standardize the methodology, (2) refinement of the Northwest SMES scenarios evaluated in the precursor study (see PNL-SA-18353), and (3) evaluation of other SMES scenarios of interest to BPA and collaborating utilities."

TECHNICAL PROGRESS TO DATE

"Project started late in March 1991. Progress to date includes planning and collection of data."

EXPECTED PROGRESS

"The study is expected to develop annual benefit/cost comparisons for SMES scenarios in the Pacific Northwest. Planned analyses will address SMES applications on the BPA system and on connecting utility systems. Aggregate benefits that appear possible under the system-specific circumstances of each scenario will be assessed."

OTHER COLLABORATION

"The study is being performed with the collaboration of BPA and connected utilities."

DNA/EPRI STUDY—BECHTEL NATIONAL, INC.

50 Beale Street
San Francisco, CA 94105-1895

EBASCO SERVICES, INC.
Madison Field Office—SMES
100 South Baldwin Street
Madison, WI 53703

DEFENSE NUCLEAR AGENCY
EPRI STUDY-RAEV
6801 Telegraph Road
Alexandria, VA 22310

ELECTRIC POWER RESEARCH INSTITUTE
3412 Hillview Avenue
P.O. Box 10412
Palo Alto, CA 94303

TECHNICAL ADVISORY GROUP
Michael J. Superczynski, Chairman
David Taylor Research Center
Annapolis, MD 21402-5067

TITLE

SMES Engineering Test Module (ETM)

STAFF

Two separate teams were headed by Bechtel National, Inc., and Ebasco Services, Inc. The principal members of each team were:

- Bechtel National, Inc.
  - Terry E. Walsh (now retired), (415) 254-7798
  - Lee McIntire, (415) 768-3288, FAX: (415) 768-1355
  - Robert J. Loyd, (415) 768-7981, FAX: (415) 768-1355

- Ebasco Services, Inc.
  - B. James Lowe, (608) 251-1166, FAX: (608) 251-3178
  - Ken Mattern, (412) 256-2360
  - Warren Moo, (212) 839-3629
- Defense Nuclear Agency
  - Lt. Col. William Dungan, (703) 325-1114, FAX: (703) 325-7366
  - Capt. David Jacobs, (703) 325-7685, FAX: (703) 325-7366
- Electric Power Research Institute
  - Robert Schainker, (415) 855-2594, FAX: (415) 855-2954
  - Terry Peterson, (415) 855-2594, FAX: (415) 855-2954
- Technical Advisory Group
  - Michael J. Superczynski, Chairman, (301) 267-2149, FAX: (301) 267-2640

FUNDING (90% DOD, 10% EPRI)

FY 1989: $7,000,000 for each team

FY 1990: $7,000,000 for each team

FY 1991: $5,000,000 total (closing costs)

APPROACH; BRIEF DESCRIPTION OF PROGRAM

The goal of the program is to design and build a 20-MWh SMES ETM prior to constructing full-scale units. Utility-size full-scale units might have stored energies as large as 5000 MWh.

The interest of DOD in the ETM is as a power source for ground-based directed-energy weapons; the interest of EPRI in the ETM is for load leveling, peak shaving, and system stabilization. The design specifications for the ETM are (i) DOD: 400 MW for 100 s and (ii) EPRI: 10 MW for 2 h (the latter requirement fixes the total stored energy at 20 MWh = 72 GJ).

Two teams were selected to compete in phase I of this work, one led by Bechtel National, Inc., and the other by Ebasco Services, Inc. Each team was supposed to create a conceptual design, including development and testing of critical items (e.g., the conductor); evaluate potential sites; and submit a phase II proposal. The original intention was to select one of the proposals for construction.

The ETM will be a large-diameter (130-m), flat, thin (low-beta) solenoid. It will be located in a subterranean trench about 10 m deep and 5 m wide, so that the Lorentz forces can be transmitted to the ground. This is an economic necessity since, as is well known, the cost of structure to support these forces would make the price of a large SMES unit impossibly high. To minimize the cost of superconductor (NbTi in both proposals), the ETM is to be operated at the lowest feasible temperature, namely, 1.8 K. At this temperature, helium is in its second liquid phase (called He-2). This phase has some unusual and additionally advantageous heat transfer properties, which are exploited in both designs.

TECHNICAL PROGRESS TO DATE

Both teams have completed phase I and have submitted voluminous and detailed reports.

The most obvious difference between the two designs is that the Bechtel team has chosen a 200-kA, 5.6-cm-diam cable-in-conduit conductor stabilized with copper and filled with noncirculating He-2, whereas the Ebasco team has chosen a 50-kA, pool-cooled conductor in the form of a 2.5-cm-diam cylinder of high-purity aluminum with eight 2.8-mm NbTi/Cu wires let into its outer surface. Both conductors have been tested; the results of the tests indicate that both will be stable in operation.

EXPECTED PROGRESS

DOD has withdrawn its support and provided $5,000,000 in this fiscal year for orderly termination of the program. The activities covered by these funds are those required to leave the program in a suitable condition to be restarted should funding become available in the future. The titles, organizations, principal investigators, and budgets of these activities are as follows:

- Thermal Hydraulic Quenchback, Oak Ridge National Laboratory, J. Winston Lue, $200,000 [(615) 574-1461, FAX: (615) 576-7926].
- Support Struts, National Institute of Standards and Technology, R. P. Reed, $1,100,000 [(303) 497-3870, FAX: (303) 497-5030].
- Proof-of-Principle Experiment, University of Wisconsin, J. Pfotenhauer, $750,000 [(608) 263-4082, FAX: (608) 263-1087].

- High-T_c Leads, Wright-Patterson Air Force Base, C. E. Oberly, $400,000 [(513) 255-4814, FAX: (513) 476-4095].
- Leak Detection, David Taylor Research Center, M. Superczynski, $200,000 [(301) 267-2149, FAX: (301) 267-2640].
- Cost Analysis Program, Bechtel, R. Loyd, $200,000 [(415) 768-7981, FAX: (415) 768-1355].
- Technical Advisory Group Final Report, David Taylor Research Center, M. Superczynski, $400,000 [(301) 267-2149, FAX: (301) 267-2640].

(The thermal hydraulic quenchback experiment at ORNL is described as a separate entry under the name of Lue, J. Winston.)

OTHER COLLABORATION

The Ebasco team included CBI, CWDC, Teledyne, the University of Wisc nsin, and Westinghouse. The Bechtel team included General Dynamics, GE, CVI, Pitt-Des Moines, and General Atomics.

DRESNER, LAWRENCE—OAK RIDGE NATIONAL LABORATORY
P.O. Box 2009
Oak Ridge, TN 37831-8040

TITLE

Design of Small SMES Solenoid

STAFF

Lawrence Dresner, (615) 574-1469, FAX: (615) 574-0584 or (615) 576-7926
J. Winston Lue, (615) 574-1461, FAX: (615) 574-0584 or (615) 576-7926
M. S. Lubell, (615) 574-1451, FAX: (615) 574-0584 or (615) 576-7926

FUNDING

FY 1991: $40,000 (ORNL)

APPROACH; BRIEF DESCRIPTION OF PROGRAM

The task is the conceptual design of a 1-kWh (3.6-MJ) energy storage solenoid of interest to the industrial partner (see below). The superconductor is NbTi, and the maximum field at the conductor is 8.0 T. The operating current should be about 1 kA and in no case should exceed 2 kA. Voltages of the order of 10 kV are foreseen (90% discharge in 1 s). Pool boiling is preferred, but forced flow may be considered. A long, slender magnet is preferred to a short, fat magnet. The design is to make the maximum use of equipment already possessed by the industrial partner, to make use of materials available to it at a good price, and to follow its present construction practices.

TECHNICAL PROGRESS TO DATE

A program has been written to survey the sizes and shapes of solenoids that (i) fulfill the requirements of an 8.0-T maximum field and a stored energy of 3.6 MJ and (ii) have an average winding current densities of 5, 7.5, 10, 12.5, and 15 kA/cm^2. The shapes admitted in the survey were long and thin: $1 < \alpha < 2$, $0.5 < \beta < 5$. A specific case was chosen for further analysis, and a pool-boiling layer winding and a forced-flow pancake winding were designed for illustrative purposes.

EXPECTED PROGRESS

The program is scheduled for completion by August 1991. An extension to HTS coil design is expected for FY 1992.

OTHER COLLABORATION

This task is being carried out under the auspices of the ORNL Superconductivity Pilot Center (Director: R. A. Hawsey). The industrial partner is Superconductivity, Inc. [President: Paul Koeppe; P.O. Box 56074, Madison, WI 53705, (608) 831-5773].

GUAZZONI, GUIDO—LABCOM

Fort Monmouth, NJ

TITLE

Utility of Small-Scale SMES for the Army

STAFF

Guido Guazzoni, Chief (20% of his time spent on SMES activity),
(908) 544-4081, FAX: (908) 544-3665
Morton Burke, (908) 544-2059 (half-time)
Lawrence Groehl, (908) 544-3531 (half-time)

FUNDING*

FY 1991: External $162,000; Internal $140,000; Equipment $10,000
FY 1992: External $200,000; Internal $150,000; Equipment $10,000 (estimate)
FY 1993: External $140,000; Internal $180,000; Equipment $20,000 (estimate)
*Note: 1 work-year of effort is costed at $50,000 without overhead.

APPROACH; BRIEF DESCRIPTION OF PROGRAM

The purpose of the program is to assess the utility of small-scale SMES for Army purposes, such as:

— Small energy storage needs, replacing lithium batteries, for which the disposal problem is serious.
— For the all-electric tank under development by TACOM (Tank Command). The energy source for the tank will be a turbine capable of supplying 1.5 MW(e). The tank will have electric motors on the wheels. The guns will be powered electrically. Some of this power will be stored in a SMES unit for pulsed powering of proactive armor (armor that is ejected from the tank and meets the incoming round in front of the tank). The all-electric tank will weigh of the order of 35 tons vs the 70 tons for conventional tanks.

The magnets must be wound out of high-T_c superconductors. Liquid nitrogen is already available on the battlefield (used for cooling certain sensors, for example), but liquid helium is out of the question. This assessment program assumes that suitable conductors will be available when needed. Fields of 15 T are foreseen.

The configuration of the coils must be toroidal to keep the stray field from affecting other equipment.

TECHNICAL PROGRESS TO DATE

The program is mainly analysis, but they have built some rings of bulk 1-2-3 material to see what persistent currents can be sustained. They are concentrating internally on the development of high-T_c superconducting switches, which they feel is an important feature of the power conditioning system. Control of power transfer is one of their central concerns. They have a cooperative program with the Kaman Scientific Corp. for the development of a superconducting switch; the program expires in November 1991. They have a conceptual idea but no working model. Their power transfer work will involve 1–2 work-years.

EXPECTED PROGRESS

The assessment will be completed in FY 1993.

OTHER COLLABORATION

They are participating in a joint program with Argonne National Laboratory (John Hull) to build a 10-kJ, 1-T coil wound from 1-2-3 material and have it ready about one year from now. They'll need a switch for this; they are negotiating with Kaman Scientific, but the details of the cost sharing have not been settled yet. They've also talked to Roger Boom, but nothing has been settled yet here, either.

HERRING, J. STEPHEN—IDAHO NATIONAL ENGINEERING LABORATORY
P.O. Box 1625
Idaho Falls, ID 83415

TITLE

Toroidal SMES

STAFF

J. Stephen Herring, (208) 525-5623

FUNDING

FY 1990: Funded as INEL Internal Exploratory R&D Project; no dollar amount available.

APPROACH; BRIEF DESCRIPTION OF PROGRAM

"A small systems code has been written to produce and evaluate self-consistent designs for toroidal superconducting energy storage units. The units can use either low temperature or hight temperature superconductors. The coils have a 'D' shape where the conductor and its stabilizer/structure is [sic] loaded only in tension and the centering forces are borne by a bucking cylinder.... A wide range of several parameters have [sic] been considered, resulting in units storing from 1 MJ to 72 GJ. Maximum fields range from 5 T to 20 T."

TECHNICAL PROGRESS TO DATE

Work completed and published as "Parametric Design Studies of Toroidal Magnetic Energy Storage Units," J. Stephen Herring, 25th Intersociety Energy Conversion Engineering Conference, Reno, Nevada, August 12–17, 1990 (EGG-89521).

EXPECTED PROGRESS

N/A

OTHER COLLABORATION

None mentioned.

LUE, J. WINSTON—OAK RIDGE NATIONAL LABORATORY
P.O. Box 2009
Oak Ridge, TN 37831-8040

TITLE

Thermal Hydraulic Quenchback Experiment

STAFF

J. Winston Lue, (615) 574-1461, FAX: (615) 574-0584 or (615) 576-7926
Lawrence Dresner, (615) 574-1469, FAX: (615) 574-0584 or (615) 576-7926
M. S. Lubell, (615) 574-1451, FAX: (615) 574-0584 or (615) 576-7926

FUNDING

FY 1991: $100,000
FY 1992: $100,000

APPROACH; BRIEF DESCRIPTION OF PROGRAM

While studying the problem of quench protection in cable-in-conduit conductors by computer simulation, members of the Bechtel design team in the DNA/EPRI study discovered a new phenomenon they called thermal hydraulic quenchback (THQ). THQ is characterized by very large propagation velocities.* THQ has not been observed directly in the laboratory, although there is very strong reason to believe that it is the cause of the extremely large propagation velocities observed in the Superconducting Super Collider (SSC) 17-m dipole magnets. Because THQ is a desirable phenomenon for protection purposes, DNA has underwritten an experiment at ORNL to search for it.

*Cold fluid elements far from a normal zone are driven through the interstices of the cable by the expansion of the hot helium in the normal zone. Because of the compression of these distant fluid elements and their friction with the cable, their temperatures rise. When their temperatures reach the current sharing threshold, the strands that they wet go normal. Quite suddenly, then, long segments of conductor become normal, causing the propagation velocity to jump to very large values.

TECHNICAL PROGRESS TO DATE

A test cable has been designed and is being fabricated: it is 50 m long and consists of seven SSC 0.8-mm strands in a 3.16-mm conduit. It will be coiled into four layers and will then fit in the uniform field region of the Coil Winding Test Experiment (CWTX) facility magnet (field up to 8.0 T). Internal heater wires will create an initial normal zone, the expansion of which will be followed by means of voltage taps, thermometers, and pressure taps.

EXPECTED PROGRESS

The program schedule calls for the experiment to be completed by December 1991.

OTHER COLLABORATION

None.

MCCONNELL, ROBERT—SOLAR ENERGY RESEARCH INSTITUTE
1617 Cole Boulevard
Golden, CO 80401-3393

TITLE

Thin Film Superconductors for Electric Power Systems

STAFF

Robert McConnell, (303) 231-1019, (FTS) 327-1019, FAX: (303) 231-1381
R. Noufi
R. Ahrenkiel
A. Nelson

FUNDING

FY 1991: $400,000

APPROACH; BRIEF DESCRIPTION OF PROGRAM

The Solar Energy Research Institute (SERI) program is a materials program dedicated to the fabrication of thin-film superconductors. SERI's interest in SMES is twofold: they see it as an enabling technology for solar energy and as a area of potential application of their thin-film superconductors.

Their goal for FY 1991 is to fabricate a thin-film superconductor with a current density of 10 kA/cm^2 having dimensions 1 cm by 10 cm. This will be done by either metal-organic chemical vapor deposition (MOCVD) or electrodeposition.

TECHNICAL PROGRESS TO DATE

As of the end of the second quarter of FY 1990, SERI made films by electrodeposition that have critical temperatures over 90 K and critical current densities at 4 K of 3 kA/cm^2.

EXPECTED PROGRESS

The goal of the program is to fabricate, by 1995, a 1-m length of a 1-kA, thin-film conductor having a critical current density of 100 kA/cm^2 at 2 T and 77 K.

OTHER COLLABORATION

SERI has extensive collaboration with the members of the Rocky Mountain Superconductivity Alliance, among which are the National Institute of Standards and Technology, Coors Ceramic Co., the U.S. Air Force, Superconductive Technologies Inc., Colorado Superconductor Inc., Ball Aerospace, Martin Marietta, Kaman Sciences Corp., US West Advanced Technologies, the University of Colorado, Colorado School of Mines, and Colorado State University.

ADDITIONAL COMMENT

More detailed information can be found in Field Work Proposal CEWSC11, dated 4/10/90.

NERENBERG, VICTORIA—BAY AREA RAPID TRANSIT DISTRICT

800 Madison Street—Lake Merritt Station
P.O. Box 12688
Oakland, CA 94604-2688

TITLE

SMES to Boost Voltage Sag in Trans-Bay Tube

STAFF

Victoria Nerenberg (Senior R&D Administrator), (415) 464-6504
Jay Burns (Project Manager), (415) 464-6690
Peter Todd, (415) 464-6695
Eugene Nishinaga, (415) 464-6477

FUNDING

FY 1991: $55,000, shared equally between BART and PG&E
FY 1992: "The Urban Mass Transit Administration has been approached for the FY 1992 procurement of a prototype."

APPROACH; BRIEF DESCRIPTION OF PROGRAM

"Due to the density of traffic through the trans-bay tube (underwater tube connecting Oakland and San Francisco) and the distance between electric substations located on the two sides of San Francisco Bay, third rail voltage sags." The objective of this program is "to explore the applicability of small-scale ... SMES devices to address the problem of third rail voltage sag.

"Small-scale SMES (8 to 10 MJ) devices will be used to store electric current which will be returned to the third rail during periods of heavy traffic to maintain voltages which will support operation of the vehicle propulsion system."

TECHNICAL PROGRESS TO DATE

"Pacific Gas and Electric (PG&E) and the Bay Area Rapid Transit District will imminently contract with Superconductivity, Inc., a private developer of SMES devices, to perform a feasibility study for this application. The expected date of execution of this contract is 4/1/91. The study is expected to take 3 months to complete."

EXPECTED PROGRESS

"Following the completion of the feasibility study, the anticipated next step will be a procurement of a prototype SMES unit for installation and testing at the Bay Area Rapid Transit District test track."

OTHER COLLABORATION

Pacific Gas & Electric; Superconductivity, Inc.

SCHOENUNG, SUSAN—W. J. SCHAFER ASSOCIATES (WJSA)
6140 Stoneridge Mall Road, Suite 385
Pleasanton, CA 94566-8004

TITLE

SMES Using High-Temperature Superconductors

STAFF (including collaborators)

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FUNDING

FY 1991: $274,000

APPROACH; BRIEF DESCRIPTION OF PROGRAM

The program is a "conceptual design study of superconducting magnetic energy storage using high temperature superconductors." The goals of the study are to (i) make a conceptual design using near-term high-temperature superconductors (HTSs) and (ii) compare it with competitive designs using low-temperature superconductors. Three stored energies, namely, 2 MWh (7.2 GJ), 20 MWh (72 GJ), and 200 MWh (720 GJ), and two HTSs, namely, BSCCO and YBCO, will be considered. Two shapes, namely, a modular torus and a low-aspect solenoid, will be studied.

TECHNICAL PROGRESS TO DATE

The first quarterly review of this program was held at DOE/HQ on February 15, 1991. At that time, dimensions for toroids and solenoids using the two HTSs and having all three energy levels were presented. For the YBCO conductor, operating at 77 K, the maximum field was 1 T, the current 2 A, and the critical current density 1 kA/cm^2. For the BSSCO conductor, operating at 20 K, fields of 2 and 10 T were considered, the current was 10 kA, and the critical current density was 20 kA/cm^2.

"During the second quarter, Task 2, Baseline Design, was completed. We have formalized the conclusion, suggested earlier, that HTS wire will need to be held in compression at all times for high temperature superconducting magnetic energy storage (HTS-SMES). Although future developments may lead to conductors that can carry tensile strain, we do not believe this is a practical near-term approach and have proceeded with our design work using modular units which pre-compress the superconductor.

"A consequence of this decision is that solenoidal configurations are now also constrained to be made up of modules, similar in construction to toroidal modules. The overall geometry of SMES units with capacities of 2, 20, and 200 MWh and using baseline HTS parameters established previously has been calculated.

"Our major effort in the HTS area during this quarter has been to address the question of stability. We have concluded that providing cryostability is impractical. Rather, our calculations show an HTS conductor to be intrinsically stable once cooled to operating temperature. Therefore, we are designing for intrinsic stability.

"Our baseline HTS is bismuth-based (BSSCO) with a small amount of silver. Details of the conductor design are still being established, but we have determined that small-diameter filaments with a twist pitch similar to conventional superconductors will be required to minimize ac losses.

"We have begun an analysis of thermal loads and refrigeration requirements.

"Also in this past quarter, General Atomics (GA) has filed an invention disclosure for a co-axial configuration that looks very attractive at fields equal to or greater than 10 T."

EXPECTED PROGRESS

"Our primary efforts in the third quarter will be to continue our thermal design and analysis, especially refrigeration requirements, and to finish the sensitivity analysis to HTS parameters." A mid-term review is scheduled for June 1991 and a final review for September 1991.

OTHER COLLABORATION

The team members are W. J. Schafer Associates; General Atomics, P.O. Box 85608, San Diego, CA 92138-5608; Argonne National Laboratory; and Advance CryoMagnetics Inc. (ACMI), 7390 Trade Street, San Diego, CA 92121.

TAM, KWA-SUR—VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
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TITLE

Improved Magnet Structure; Innovative Applications

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FUNDING

FY 1988: $12,500
FY 1989: $47,335
FY 1990: $24,075
FY 1991: $19,451
FY 1992, FY 1993: TBD to be determined

APPROACH; BRIEF DESCRIPTION OF PROGRAM

The emphasis is on "(1) new or improved SMES magnet structure and (2) innovative applications of SMES systems." The program is sponsored by the Virginia Center for Coal and Energy Research, Center for Innovative Technology, E. I. duPont de Nemours & Company.

TECHNICAL PROGRESS TO DATE

"(1) Identified factors that affect SMES magnet performance in terms of material utilization, energy density, support structure and stray field."

"(2) Proposed and studied several new applications of SMES in power systems."

EXPECTED PROGRESS

"(1) A new (patentable) magnet structure for SMES applications."

"(2) More innovative applications of SMES systems."

OTHER COLLABORATION

None reported.

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