Fall, 2005 Date of Issue: October 17, 2005

Superconductivity Web21

Published by International Superconductivity Technology Center
5-34-3, Shimbashi, Minato-ku, Tokyo 105-0004, Japan Tel: 03-3431-4002, Fax: 03-3431-4044

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Published by International Superconductivity Technology Center
5-34-3, Shimbashi, Minato-ku, Tokyo 105-0004, Japan
Tel: +81-3-3431-4002 Fax: +81-3-3431-4044
Top of Superconductivity Web21: http://www.istec.or.jp/Web21/index-E.html

This work was subsidized by the Japan Keirin Association using promotion funds from the KEIRIN RACE

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Forum on Superconductivity Technology Trends 2005

On Monday, May 30 2005, ISTEC held a forum on superconductivity technology trends, entitled "Superconductivity Technology Entering the Commercialization Period" at Toshi Center Hotel in Tokyo, attended by about 250 persons including personnel from industrial and academic circles, the government, the press and the public sector. Results, issues and trends in the superconductivity technology development for industrialization were reported and enthusiastic discussions took place.

Koichiro Nakamura, Director, Research and Development Division, Industrial Science and Technology Policy and Environment Bureau, Ministry of Economy, Trade and Industry, and Kazuaki Koizawa, Director General, New Energy Technology Development Department, New Energy and Industrial Technology Development Organization (NEDO), delivered congratulatory messages. In their messages, the two guests encouraged those attended the meeting saying, "The results of research and development indicate that the commercialization of the superconductivity technology is approaching and that what is needed more in the future is defining research and development targets based on a hard look at the future image and distinguishing market potentials.

In a keynote lecture entitled "Superconductivity Technology Entering Commercialization Period," Shoji Tanaka, Director General, Superconductivity Research Laboratory (SRL) of ISTEC, remarked, tangible results of high-temperature superconductivity technology development have been obtained recently in various fields, moving closer to full commercialization, and future images toward 2010 to 2020 are being shaped with the prospect of application to new domains from quantum computers to nuclear fusion becoming real.

Director General Shoji Tanaka of SRL gave the keynote speech

Setsuko Tajima, Senior Staff, SRL/ISTEC, reported guidelines toward the sophistication of wire characteristics (high Jc and characteristics stabilization and homogenization) by defining parameters to be controlled such as composition and heat treatment and by feeding them back for characteristics enhancement.

Izumi Hirabayashi, Director, Bulk Superconductor Laboratory, Division of Material Science & Physics, SRL/ISTEC, reported the discovery of a new material (Gd210) by analyzing samples obtained in space experiments that made the fabrication of large, high-performance bulk feasible through a new synthesis method applying the new material. Dr. Hirabayashi introduced applications to various industrial fields through dramatic improvement in supplementary magnetic field characteristics through recent technology development and in mechanical strength through resin impregnation and other techniques.

Entitled "Traveling Performance of Superconductivity Technology Magnetic Levitation Guide and

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Application to Transfer Systems," Makoto Okano, National Institute of Advanced Industrial Science and Technology (AIST), spoke about design, prototyping, traveling characteristics and future issues of a magnetic levitation system that uses bulk superconductors.

Naoki Koshizuka, Deputy Director, Morioka Laboratory for Applied Superconductivity Technology, SRL/ISTEC, reported the technical prospects for a 100kWh-class FW superconducting bearing as a result of the Superconducting Bearing Technology Project for flywheel electric power storage. Dr. Koshizuka also reported factory running tests for a 10kWh-class electric power storage system, a success in electric power storage largest in the world in scale by superconducting levitation on a radial bearing and other matters.

Yuh Shiohara, Director, Division of Superconducting Tapes & Wires, SRL/ISTEC, reported the most recent status of accomplishment of a high critical current density, which is a target of the Applied Basic Project, technology development for the long-length wire manufacturing process and efforts made in the research of machinability toward commercialization in the future.

Toshio Takeda, Ishikawajima-Harima Heavy Industries, Ltd. reported the technology development history of a marine high-temperature superconducting motor undertaken jointly by industry and academia showing motion-picture footage. Dr. Takeda outlined future marketing strategies, giving the audience the impression that superconductivity technology is reaching the commercialization stage.

Keiichi Tanabe, Director, Division of Electronic Devices, SRL/ISTEC, reported the progress made by the Low Power Consumption Superconducting Network Device Development Project. Dr. Tanabe reported recent results and future issues including the integration of one million junctions in a niobium-system LSI using an advanced process and operation of a 4x4 switch at 45 GHz through the development of an SFQ logic synthesis circuit in the development of low-temperature devices and the development of the superconducting 4-layer stacking process and the operational verification of a 100-junction class high-temperature SFQ (single flux quantum) circuit in the development of high-temperature devices.

Kazuyuki Izawa of Tohoku Electric Power Co.,Inc. briefed the audience on the development status of a traveling SQUID nondestructive examination system. Dr. Izawa reported building a system that conducts the nondestructive inspection of defects in weld zones in the field by curbing impact by environmental magnetic noise and noise by caused by the moving of an SQUID (superconducting quantum interference device).

Shigeo Nagaya of Chubu Electric Power Co, Inc. briefed the audience on development in Phase II of SMES (superconducting magnetic energy storage) sponsored by NEDO. The project is designed to verify SMES system technology featuring both economy and performance through the development of an oxide coil, low-cost converter, high-reliability cryocooler and current lead based on results of past development and real system link tests. The progress made and future challenges were reported.

As a summary lecture, Osami Tsukamoto, Professor, Yokohama National University, delivered a keynote lecture entitled "Status and View of Development of Superconducting Applied Equipment by Various Countries." In his keynote lecture, Prof. Tsukamoto summarized the importance of power supply systems such as infrastructure and superconducting cables, fault current limiters and other equipment developed by various countries in the application of superconductivity technology to power equipment for electric power

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systems.

Hisao Hayakawa, Professor Emeritus, Nagoya University, delivered a keynote lecture on recent trends in superconducting electronics. Prof. Hayakawa noted that there were issues to be solved. For example, low integration-scale improvements need to be made in power sources and other areas even though many remarkable results have been achieved recently in SFQ research including process, circuit design and other technologies, but that there were high expectations of the results of research on implementation technologies at the system level such as low- and room-temperature interfaces, multi-chip modules and a cryogenic environment toward the commercialization of superconductivity technology.

This forum provided an opportunity to recognize again the significance and importance of making further research and development efforts jointly by industry, academia and government triggered by the steady results that could be achieved in research and development in various superconducting fields while the first step could be taken toward commercialization.

Lecture scene

(Masaharu Saeki, Director, Research & Planning Department, ISTEC)

(Published in a Japanese version in the July 2005 issue of *Superconductivity Web 21*)

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What's New in the World of Superconductivity (August)

Power

SuperPower, Inc. (August 3, 2005)

SuperPower, Inc., a subsidiary of Intermagnetics General Corporation (IMGC), has achieved a world record performance of more than 100 A in a 206-meter length of 2G HTS wire, for an amp-meter performance of 22,000 amp-meters. This performance more than doubles the previous one announced by SuperPower in January 2005 and surpasses the previous world record. Glenn H. Epstein, chairman and chief executive officer of IMGC, commented, "The increase in piece lengths of 2G wire beyond the 100 meter threshold is of particular significance as we work toward product commercialization and [the] development of devices incorporating 2G wire." SuperPower's new 2G wire is about 35 – 50% thinner than previous versions, an accomplishment that was achieved by reducing the thickness of the wire substrate. The new wire has been used in a prototype electrical coil developed at the Los Alamos National Laboratory to demonstrate the mechanical durability of the conductor.

Source:
"Intermagnetics' SuperPower Subsidiary Sets New World Record in Second-Generation HTS Wire Performance"
Intermagnetics General Corporation press release (August 3, 2005)
http://phx.corporate-ir.net/phoenix.zhtml?c=88261&p=irol-newsArticle&ID=739115&highlight

American Superconductor (August 3, 2005)

American Superconductor Corporation (AMSC) has achieved several significant benchmarks in the commercialization of 2G HTS wire, including record lengths of a new three-ply, 4.4-mm-wide wire; the fabrication and testing of the first electromagnetic coil using this wire (which produced a magnetic field of 0.32-Tesla at Oak Ridge National Laboratory), and record 2G wire performance levels. Previously, only 1-cm wide 2G wires had been produced in comparable lengths. The 4.4-mm wires are produced using AMSC's reel-to-reel manufacturing process from 4-cm wide strips that are slit to produce the tape-shaped wires. The resulting wires are then laminated with copper or other metals. Using this process, a single pass of a 4-cm wide strip through each of the manufacturing steps yields eight HTS wires after slitting. These benchmarks will advance the practicality of 2G wire by increasing its electrical and mechanical stability and reducing manufacturing costs. AMSC is on track to initiate regular production runs of 100-meter 2G wire within the current financial quarter and to demonstrate all aspects of its proprietary 2G HTS wire manufacturing technology by December 2005. The company expects to ship approximately 10,000 meters of 344 superconductor wire to customers during the next 12 to 15 months and to reach a manufacturing capacity of 300,000 meters/year by December 2007.

Source:
"American Superconductor Achieves Important Benchmarks for Commercialization of Second Generation High Temperature Superconductor Wire"
American Superconductor press release (August 3, 2005)
http://phx.corporate-ir.net/phoenix.zhtml?c=86422&p=irol-newsArticle_Print&ID=739161&highlight

American Superconductor Corporation (August 4, 2005)

American Superconductor Corporation has announced its first quarter(2006) financial results for the

period ending June 30, 2005. Revenues decreased by 4% to US $12.2 million, compared to the same period in the previous fiscal year. The net loss for the quarter was $5.6 million, compared with $4.9 million for the same period in the previous fiscal year. The company ended the quarter with cash, cash equivalents, and short- and long-term investments equal to $81.5 million and no long-term debt, compared with $87.6 million at the end of the previous quarter. The company received $2.4 million in new orders and contracts during the first quarter, and its total backlog of orders and contracts at the end of the first quarter was $24.3 million. Greg Yurek, President and CEO, commented, "Based on our current revenue visibility and on prospects for new orders during the remainder of this fiscal year, we are confirming our guidance of $55 million to $65 million in revenues for fiscal 2006. Prospects for new orders for industrial and wind farm D-VAR(R) systems and the substantial likelihood of one or more new U.S. Navy contracts for HTS rotating machines, in addition to our current revenue visibility, continue to point to a stronger second half than first half. We are also encouraged by the imminent signing of the Energy Bill into law, which should give rise to additional orders and contracts that will strengthen our backlog and provide a source of revenue growth beyond this fiscal year. The new Energy Bill authorizes spending of whatever sums are necessary to carry out these HTS cable projects, which are essential for the rapid adoption of HTS power cables to help solve the nation's power grid problems. In addition to the Energy Bill, the U.S. Senate's increase to the Department of Energy's budget for the Superconductivity Program by $5 million… coupled with the DOE's recently announced intent to solicit new superconductor demonstration projects bodes well for the creation of new sales opportunities for our HTS wire." The Energy Bill is also expected to stimulate opportunities for the sale of D-VAR and SuperVAR systems to wind farms and utilities, and American Superconductor expects this area to be the source of its largest business growth during the next fiscal year.
Source:
"American Superconductor Reports Fiscal 2006 First Quarter Results"
American Superconductor Corporation press release (August 4, 2005)
http://phx.corporate-ir.net/phoenix.zhtml?c=86422&p=irol-newsArticle_Print&ID=739539&highlight

Siemens (August 15, 2005)

Siemens has announced the operation of the first HTS generator for ship propulsion. The new HTS generators are rated at 4 MVA, extremely efficient, and almost half the weight and volume of conventional generators employing copper magnet coils. The new generator will be suitable for application in cruise ships and large motor yachts. Siemens Corporate Technology and the Siemens Business Groups Industrial Solutions & Services/ Industrial Plants/Marine Solutions (I&S IP MAS) and Automation & Drives/Large Drives (A&D LD) jointly developed the HTS generator, while European Advanced Superconductors GmbH & Co. KG (EAS) supplied the HTS wire. The generator utilizes a neon-based cooling system. The generator was developed with funding from the German Federal Ministry for Education and Research (BMBF) and will now enter a period of extensive system testing.
Source:
"Economical Ships Thanks to Superconductivity"
Siemens press release (August 15, 2005)
http://www.siemens.com/index.jsp?sdc_p=fmls5uo1290499ni1079175pcz3&sdc_bcpath=1178916.s_5%2C&sdc_sid=234297351348&

SuperPower, Inc. (August 31, 2005)

SuperPower, Inc. has announced that the BOC Group has successfully installed and tested the cryogenic refrigeration system (CRS) for the Albany HTS Cable Project. The cryogenic system meets the highest industrial-level reliability requirements and can handle real events that occur in live power grids,

including fault currents. BOC will remotely monitor the cable and cooling system from its Remote Operations Center in Pennsylvania. The next step will be the installation of 350 meters of superconducting cable. Sumitomo Electric Industries has completed and shipped the first phase of the cable, which is expected to arrive at the cable site in September 2005.
Source:
"Intermagnetics' SuperPower Subsidiary Announces Progress at Albany HTS Cable Project"
SuperPower, Inc. press release (August 31, 2005)
http://www.igc.com/news_events/news_story.asp?id=163

Material

Superconductive Components Inc. (August 1, 2005)

Superconductive Components, Inc. has announced its second quarter financial results for the quarter ending June 30, 2005. Total revenues increased by 7.9% to US $713,535, compared with the results for the same period in fiscal 2004. Product revenues increased by 5.4% to $624,002 as a result of sales to new and existing customers. Contract research revenues also increased to $89,533, compared with $69,374 for the same period in the previous fiscal year. This revenue was mainly due to a Phase II Small Business Innovation Research grant from the U.S. Department of Energy. Dan Rooney, Chairman, President and Chief Executive Officer, commented, "Our results for the second quarter of 2005 reflect further progress in key areas of our business. Revenues for the most recent quarter were the highest since the third quarter of 2002, and bookings reached their highest level since the third quarter of 2003... We anticipate additional gross margin improvement in future quarters. Operating expenses are expected to grow at a slower rate than revenue for the foreseeable future. Together, these achievements will contribute to improved long-term performance."
Source:
"Superconductive Components, Inc. Reports Improved Second Quarter Results"
Superconductive Components, Inc. press release (August 1, 2005)
http://www.targetmaterials.com/ne/earnings/scci25.htm

Communication

Superconductor Technologies Inc. (August 3, 2005)

Superconductor Technologies Inc. has announced its second quarter financial results for the period ending July 2, 2005. Total net revenues increased by 36% to US $8.6 million, compared with the results for the same period in the previous fiscal year. Net commercial product revenues increased by 67% to $7.6 million. Government and other contract revenue amounted to $972,000, compared with $1.8 million for the same period in the previous fiscal year. Net loss for the second quarter decreased to $2 million, compared to $8.9 million for the same period in fiscal 2004. The increase in commercial product revenue was credited to actions intended to increase sales efficiency. The company also reduced its inventory levels by $2.6 million in the second quarter. As of July 2, 2005, the company had a commercial product backlog of $333,000, compared with $5.1 million at the end of the previous quarter. This decrease reflects a large order that was placed at the end of the first quarter and was shipped during the second quarter. At the end of the second quarter, the company had $10.2 million in working capital, including $6.7 million in cash and cash equivalents.

Source:
"Superconductor Technologies Inc. Announces Second Quarter 2005 Results"
Superconductor Technologies Inc. press release (August 3, 2005)
http://phx.corporate-ir.net/staging/phoenix.zhtml?c=70847&p=irol-newsArticle&ID=739298&highlight

Superconductor Technologies Inc. (August 11 and 16, 2005)

On August 11, Superconductor Technologies Inc. announced that it had obtained commitments for the sale of US $12.5 million of securities in a registered direct offering. The transaction, which was closed on August 16, consisted of the sale of approximately 17 million shares of common stock plus five-year warrants for an additional approximate 3.4 million shares at an exercise price of $1.11 per share to a select group of institutional investors. The offering generated net proceeds of $11.4 million. Each investor has also been given a 90-business day option to purchase, at the same price, an additional amount of the offered securities equal to 20% of their initial purchase. If all of these additional options are exercised, STI will generate an additional $2.3 million in gross proceeds at a second closing in December 2005.

Source:
"Superconductor Technologies Inc. Announces $12.5 Million Registered Direct Offering"
Superconductor Technologies Inc. press release (August 11, 2005)
http://phx.corporate-ir.net/staging/phoenix.zhtml?c=70847&p=irol-newsArticle&ID=742267&highlight
"Superconductor Technologies Closes $12.5 Million Directed Public Offering"
Superconductor Technologies Inc. press release (August 16, 2005)
http://phx.corporate-ir.net/staging/phoenix.zhtml?c=70847&p=irol-newsArticle&ID=743807&highlight

ISCO International, Inc. (August 22, 2005)

ISCO International, Inc. has released a third-quarter financial update. Based on orders through to the middle of the third quarter, ISCO International's quarterly revenue was approximately $1.3 million and its year-to-date revenue exceeded $7 million – nearly three times the full-year sales of $2.6 million for 2004. ISCO also announced that it has received its first RF2 order from a potentially significant new account as well as a major customer commitment for a field trial of its newly released PCS product line.

Source:
"ISCO INTERNATIONAL PROVIDES BUSINESS UPDATE"
ISCO International, Inc. press release (August 22, 2005)
http://www.iscointl.com/

Accelerator

Oak Ridge National Laboratory (August 19, 2005)

The Oak Ridge National Laboratory has announced a milestone toward the completion of the Spallation Neutron Source (SNS) facility in June 2006 – the operation of the superconducting section of its linear accelerator. The SNS linac has two sections: a room-temperature section that was commissioned last January and a superconducting, or cold, section. The cold linac will provide most of the power driving the linac and has already achieved an energy level of 865 MeV (about 75% of the speed of light). The SNS linac is the world's first high-energy, high-power linac to utilize superconducting technology for the

acceleration of protons.
Source:
"'Cold linac' commissioning major step for ORNL's Spallation Neutron Source"
Oak Ridge National Laboratory press release (August 19, 2005)
http://www.ornl.gov/info/press_releases/get_press_release.cfm?ReleaseNumber=mr20050819-00

Basic

Cornell University (August 25, 2005)

Researchers at Cornell University's Laboratory of Atomic and Solid State Physics have shown how adding charge-carrying atoms, like oxygen, to a superconductor can increase the material's overall ability to conduct electricity but decrease it in localized spots. Using scanning tunneling microscopy, the researchers were able to identify the locations of individual oxygen atoms within a particular superconductor's molecular structure and then used this information to examine how the atoms affected current flow in the atoms' immediate vicinity. They found that the locations of the oxygen atoms were correlated with previously identified areas of energy disorder. The oxygen atoms appear to be working in two different ways: on average and locally. "This kind of information is a necessary step toward understanding first the mechanism of high-temperature superconductivity and, next, how to raise the transition temperatures," said James Slezak, a graduate student in physics at Cornell. The research was published in the August 12 issue of Science.
Source:
"Researchers identify location of crucial atoms and move closer to elusive goal of creating high-temperature superconductor"
Cornell University press release (August 25, 2005)
http://www.news.cornell.edu/stories/Aug05/Davis.superconductors.lg.html

(Published in a Japanese version in the October 2005 issue of *Superconductivity Web 21*)

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Feature Articles : Refrigerating and Cooling Technology for Superconducting Apparatus
- Current Status of Refrigerating Technology for Superconducting Apparatus -

Katsuhiko Ito
Engineering Department, Cryogenics Division, Precision Equipment Group
Sumitomo Heavy Industries, Ltd.

The advances made in the superconductivity technology and low-temperature heat-insulation technology have expanded the market for cryocoolers. The market has expanded to new segments such as superconducting MRI and Magnetic field applied Czochralski method to make silicon crystal. The prospects are good for new fields also such as SMES (superconducting magnetic energy storage), fault current limiters and transformers that have been topic items parallel with the recent advances in high-Tc superconducting wires. The cooling method for superconducting apparatus has also advanced from cooling by cryogens as in the past to radiation shield cooling using a 10-K GM cryocoolers and recondensing of liquid He with 4-K cryocooler. The application of a 10-K GM cryocooler has reduced the cryogen refilling interval, which was cumbersome, and recondensing with 4-K GM cryocooler has eliminated the radiation shield thereby allowing cost reduction and a reduction in the consumption of liquid He, which is a precious resource. Needless to say, these advances in cooling technology have been made possible through market principles including ease of operation of superconducting apparatus and a low system price. The total number of 4-K cryocoolers for MRI is expected to be more than 10,000 units in a few years.

4-K pulse tube cryocooler

Superconducting apparatus that uses the conduction cooling system by a 4-K GM cryocooler features the elimination of liquid He, which is difficult to handle, and ease of startup, merely by operating a switch. Because of these features, they have expanded their customer base centering on research application. At present, they are used in some MRI and silicon pulling systems. The refrigerant dipping, refrigerant circulation and other systems have been used as cooling systems, and these systems have both advantages and disadvantages. When viewed from the users' viewpoint, the preferred cooling system for superconducting apparatus is believed to be conduction cooling. The reliability of cryogenic cooling systems is a future challenge. GM cryocoolers have a moving part in their low-temperature units and their sliding parts wear over time when operated for a long time, requiring periodic maintenance. When the reliability of superconducting apparatus is examined, refrigerating systems obviously have high weight. The 4-K pulse tube cryocoolers that have accomplished prominent advances in recent years are reputed to have high reliability because of no moving parts in their low-temperature region. Nevertheless, several issues remain to be solved before they are recognized for industrial application.

On the other hand, high-Tc superconducting wires are accomplishing prominent advances and are bringing about new potential for superconducting apparatus. A high cooling temperature reduces the load to the cooling system, and these wires can be used in combination with a refrigeration system with lower power consumption. Expectations are high from the standpoints of environment conservation and energy saving. The conduction cooling system that uses a large Stirling pulse cryocooler featuring high efficiency is promising as an application to these areas. It is clear that the technology development of cooling systems for superconducting apparatus will also coexist with advances in superconductivity technology in the future.

(Published in a Japanese version in the June 2005 issue of *Superconductivity Web 21*)

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Feature Articles : Refrigerating and Cooling Technology for Superconducting Apparatus
- Evolution of Technology for Pulse Tube Cryocooler -

Tomiyoshi Haruyama
Particle and Nucleus Research Institute
High Energy Accelerator Research Organization

Compared with GM cryocoolers, pulse tube cryocoolers have lagged behind in refrigerating capacity even though they excel in vibration and ease of maintenance servicing, but their performance is gradually improving. Their application as real cryocoolers has started in a wide temperature range. In superconducting apparatus cooling of a 4-K level, there are high expectations for superconducting magnets installed on superconducting magnetically levitated trains (superconducting linear motor cars) and for cooling of MRI magnets at low vibration. However, there are as yet no reports on specific examples.

Research and development of pulse tube cryocoolers (type GM) that generate large refrigerating capacity of more than 150 W at 80 K is advancing for the recondensation of liquid nitrogen in the radiation shield cooling of superconducting magnetically levitated trains. [1)] Research on Stirling pulse tube cryocoolers is also being conducted to efficiently accomplish large refrigerating capacity at 80 K. High efficiency can be achieved by eliminating loss caused by the rotary valve, and 200 W at 77 K has been accomplished in an experiment. [2)]

Even though not related to the cooling of superconducting apparatus, several reports have been submitted in the scientific research fields of physics and medicine focusing on the features of pulse tube refrigerating systems. Research and development of pulse tube refrigerating systems of 4 K and 80 K levels with vibration reduced to the order of nanolevel is being conducted to cool the mirror of laser interferometers for the detection of gravity waves. Based on a 4-K pulse tube refrigerating system on the market in Japan, the performance of 0.5 W at 4.5 K + 15 W at 44 K and of vertical vibration of 50 nm or less at the low-temperature end could be accomplished by incorporating a unique technology for vibration reduction. [3)] Four and six pulse tube refrigerating systems for 4 K and 80 K have been installed in the ground of Kamioka Mine, where ground surface vibration is very small, and are on test runs as an important elemental technology of a system for the verification of gravity wave detection. (See figure)

The 4-K and 80-K low-vibration pulse tube refrigerating systems for cooling a gravity wave detection mirror installed in the ground of Kamioka Mine.

The pulse tube refrigerating system is also used for detecting particles. Liquid xenon has excellent sensitivity to high-energy particles and is used in low-temperature liquid detectors. The boiling point of liquid xenon at an atmospheric pressure is 165 K, and cooling and recondensation has been performed by liquid nitrogen. However, temperature control with high precision is difficult, and a cryogen is needed. For these reasons, a pulse tube refrigerating system capable of refrigerating as high as about 200 W at 165 K has been developed, achieving a liquid xenon detector that does not use liquid nitrogen at all. [4)] Application at temperatures in the neighborhood of 165 K have been tested such as dark material search using liquid xenon, and the cooling of PET systems and semiconductor silicon detectors. These experiment systems handle very weak lights and electrons over a long time, and the features of the pulse tube refrigerating system with little vibration and easy maintenance are utilized.

In medicine, compact pulse tube refrigerating systems have been developed for low-temperature medical treatment, especially the treatment of patients with skin diseases. A refrigerating capacity of 10 W at 170 K has been set as a target for skin refrigerating, replacing the liquid nitrogen used in the past. A model system using a Stirling compressor driven at 50 Hz has been prototyped, accomplishing performance that almost achieves the target value. [5)]

References:

1) Y. Kondo et al., Cryocoolers 13, Springer, New York, 2005, pp. 681 - 687
2) Otani et al., Abstracts of CSJ Conference, Vol. 70 (2004), p. 119
3) T. Tomaru et al., Cryocoolers 13, Springer, New York, 2005, pp. 695 - 702
4) Haruyama et al., Abstracts of CSJ Conference, Vol. 71 (2005), p. 74
5) P. E. Bradley et al., Cryocoolers 13, Springer, New York, 2005, pp. 671 - 679

(Published in a Japanese version in the June 2005 issue of *Superconductivity Web 21*)

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Feature Articles : Refrigerating and Cooling Technology for Superconducting Apparatus
- Development of Cryogenic System for Superconducting Motors -

Shigeru Yoshida
Cryogenic Project
Taiyo Nippon Sanso Co.

In January 2005, an industry-academia cooperative research group including Taiyo Nippon Sanso developed a superconducting motor (superconducting magnetic field coil) of a practical level cooled by liquid nitrogen for the first time in the world. Following this event, in April 2005, an all-superconducting motor (superconducting magnetic field coil and superconducting armature coil) was announced. Both the superconducting motor and all-superconducting motor output 12.5 kW at a rotational speed of 100 rpm and use the same cooling system. The difference is that a cryostat for the superconducting armature coil is added to the all-superconducting motor.

A flow diagram of the cryogenic system is shown in Fig. 1. The liquid nitrogen supply system is equipped with a GM cryocooler capable of 200 W at 80 K. The cryocooler is operated at a constant temperature of 64 K by an electric heater incorporated in the cold head. The GM cryocooler cools the liquid nitrogen in the system to a sub-cooled state at 66 K under atmospheric pressure, and the liquid nitrogen is fed to the cryostat by the liquid nitrogen pump. The circulation flow rate of the sub-cooled liquid nitrogen is about 1 L/min, and liquid nitrogen of 68 K is returned.

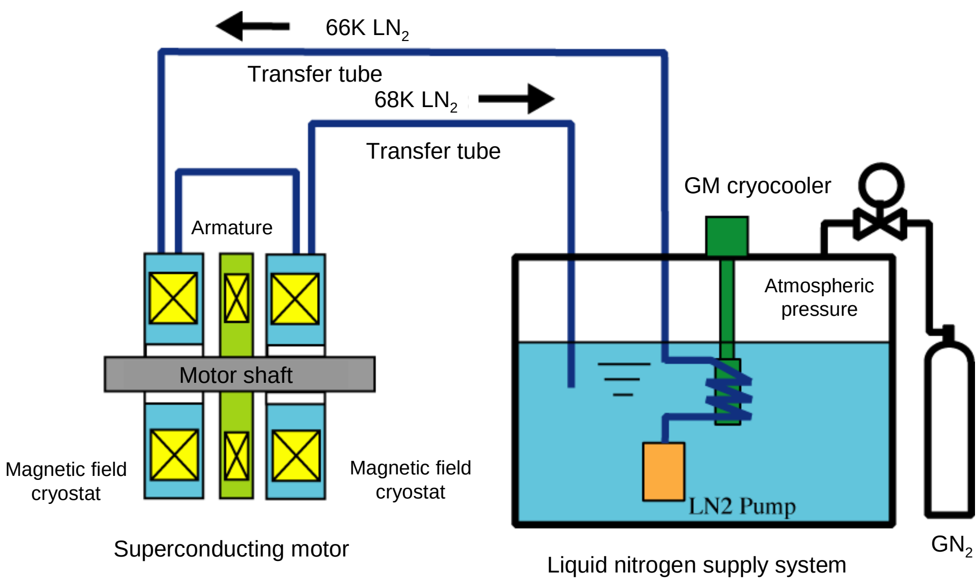

Fig. 1 Flow diagram of the cryogenic system for the superconducting magnetic field motor

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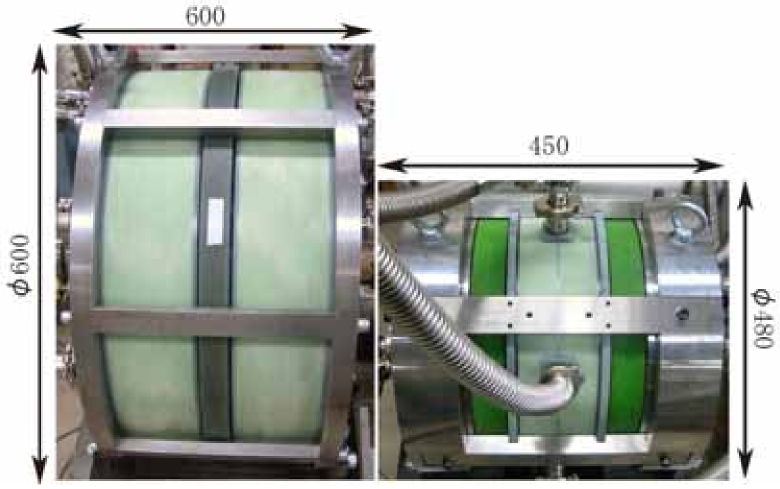
The heat load of an entire cryogenic system confirmed by the refrigerating capacity of the cryocooler was about 60 W when the motor operated under no load. In estimations, the heat leak of the cryostat and current leads is about 20 W, and heat leak into the transfer tube and liquid nitrogen supply system is about 40 W compared to about 60 W of the heat load mentioned above. Therefore, the total heat leak is almost as designed.

Fig. 2 shows photos of the superconducting magnetic field motor and the all-superconducting motor. Considering that the motors were alternating current machines, the motor cryostats were made of FRP (fiber reinforced plastic). To achieve compactness, which is an important feature of the superconducting motor, the vacuum insulation layers are very thin, 3 to 5 mm. Compared with metals, the Young's modulus of FRP is small, and the vacuum insulation layers may be crushed by deformation caused by atmospheric pressure. The motor cryostat therefore incorporates some ideas to prevent crushing. Unlike the installation direction of usual cryostats, the motor cryostat is installed transversely. To allow the superconducting coils inside the cryostat to be uniformly immersed in liquid nitrogen in this condition, it is absolutely necessary to avoid nitrogen gas from remaining inside the cryostat. For this reason, the inside of the cryostat and transfer tubes is filled with sub-cooled liquid nitrogen that is circulated by a pump.



Superconducting magnetic field motor | All-superconducting motor

Fig. 2 Full views of the superconducting motors

These superconducting motors have been developed as motors for marine POD propulsion systems, but their uses are not restricted in marine, and they can be used with land equipment as well. As in this case, recent research and development of high-temperature superconducting power application is tackling development tasks for practical equipments. As a result, there have been more examples where sub-cooled liquid nitrogen is used as a coolant. Sub-cooled liquid nitrogen is low priced, excels in electrical insulation characteristics and environmental conservation performance, and is expected to have multiple uses as a refrigerant.

(Published in a Japanese version in the June 2005 issue of *Superconductivity Web 21*)

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Feature Articles : Refrigerating and Cooling Technology for Superconducting Apparatus
- Development of Refrigerant Circulation Technology for Superconducting Cables -

Shinichi Mukoyama
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The Furukawa Electric Co., Ltd.

Cables in lengths of several kilometers have to be cooled by the circulating liquid nitrogen (77 K) in them to use superconducting cables in real applications. The long-distance circulation of liquid nitrogen has had to be verified in detail. In a project sponsored by the Ministry of Economy, Trade and Industry, the Central Research Institute of Electric Power Industry and The Furukawa Electric Co., Ltd. jointly conducted a field test of a 500-m superconducting cable (see Fig. 1) as part of a program, "Research of Basic Technologies for AC Superconducting Power Apparatus," contracted by the New Energy and Industrial Technology Development Organization (NEDO) to Super-GM.

Fig. 1 Structure of the 500-m superconducting cable (Super- Ace Project, NEDO)

What is most important for a cooling system of a high-temperature superconducting cables is for liquid nitrogen to function as a cooling medium of the cable and as an impregnant for electric insulation. The cryogenic electric insulation of superconducting cables achieve high insulation performance by laminating insulating paper on the conductor and by impregnating liquid nitrogen in the insulating paper. This system requires the circulation of liquid nitrogen in sub-cool conditions, in which liquid nitrogen does not boil, to prevent bubbles in the insulator. Bubbles in the insulator cause partial discharge that triggers dielectric breakdown. The circulation of liquid nitrogen in sub-cool conditions is also desirable from the standpoint of pressure loss. Loss of superconducting cables (AC loss, heat import, viscosity loss and other losses) is cooled by the specific heat portion of the circulating liquid nitrogen.

The cooling system for the 500-m superconducting cable feeds pressurized liquid nitrogen by a circulation pump and feeds and circulates liquid nitrogen to the cable after cooling it by Stirling cryocoolers. The system configuration for the cooling system and the 500-m superconducting cable is shown in Fig. 2. The system is divided into two systems, a terminal cooling system and a cooling system for the superconducting cable. Liquid nitrogen circulates in them independently. By separating the cooling system for the air terminals, heat import to the cable from the air terminal is prevented, enhancing accuracy in measuring cable cooling characteristics. At the same time, heat import from the air terminal in the initial cooling phase is curbed, shortening the initial cooling period. Liquid nitrogen is pressurized by pressurizing a liquid nitrogen reservoir by nitrogen gas. Initially, He gas was used as pressurized gas. A problem with He is that He gas dissolved in liquid nitrogen generates bubbles at a height of 10 m, which was lowest in pressure in the system. Since then, nitrogen gas, which is also a refrigerant, has been used as pressurized gas.

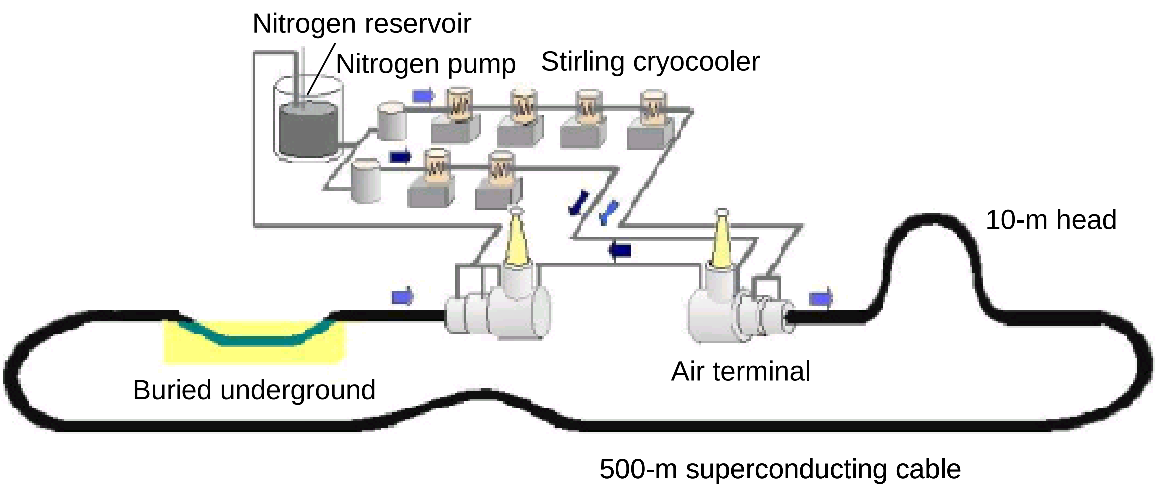

Fig. 2 System for the field test of the 500-m superconducting cable

Tests to check whether this cooling system could be terminated without major problems after about 5000 hours' operation were conducted. Shut-down tests of stopping the cryocoolers and the pumps assuming cooling system trouble were performed to verify that a current could be inputted to the cable for several hours without partial discharge. Lastly, some people initially doubted the circulation of liquid nitrogen over a long distance. However, liquid nitrogen could be circulated easily and stably. Enhancement in refrigerating capacity and in cooling efficiency is future tasks concerning cooling systems for superconducting cables.

(Published in a Japanese version in the June 2005 issue of *Superconductivity Web 21*)

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Feature Articles : Refrigerating and Cooling Technology for Superconducting Apparatus
- View of Cryocooler for MRI -

Michio Shimizu
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Oxford Instruments KK

In the dawning period of MRI in the first half of the 1980s, superconducting magnets for MRI were provided with two layers of heat shields, a 77-K shield cooled by liquid nitrogen and a 20-K shield cooled by evaporated helium gas. Liquid nitrogen had to be replenished every week and liquid helium, every month. Models that combined a liquid nitrogen tank and a GM cryocooler to prevent the evaporation of liquid nitrogen were then introduced. In the mid-1980s, liquid nitrogen was no longer needed, and two-stage 10-K GM cryocoolers to cool two layers of shields, 70 K and 20 K became popular. A system to reliquefy evaporated helium by a two-stage 4-K GM cryocooler is the main focus at present. This system has one shield layer that is cooled by the first stage of the GM cryocooler.

Pulse tube cryocoolers, whose performance has been improved recently, have no moving parts and cause less vibration and noise. Vibration is not a major problem with MRI, but low noise is a great advantage because it causes less discomfort to patients.

By equalizing the dimensions of the flange of the room-temperature part and two cooling stages of the

Fig. 1 4-K GM cryocooler (left) and 4-K pulse tube cryocooler (right)
(Sumitomo Heavy Industries, Ltd.)

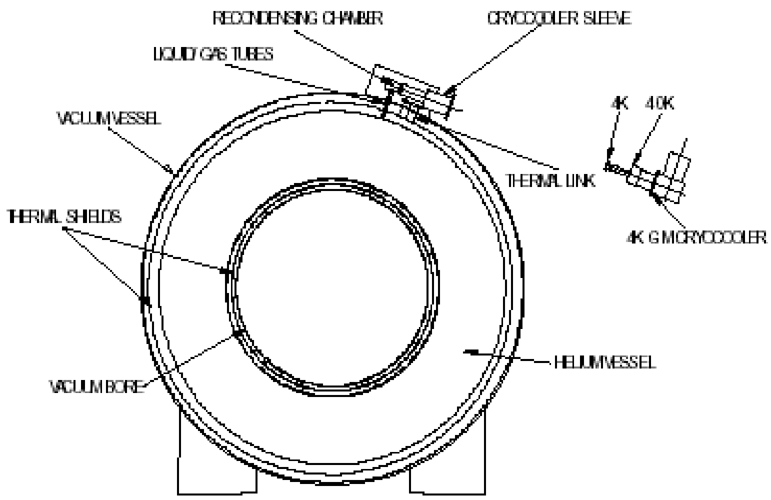

Fig. 2 Structure of magnet with a 4-K GM cryocooler
(Cryocooler installed transversely, GE)

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pulse tube cryocooler and those of the GM cryocooler, the 4-K GM cryocooler of the existing MRI magnet may be easily changed to a 4-K pulse tube cryocooler. The crux of the problem is the direction of the cryocooler. The pulse tube cryocooler cannot demonstrate its capacity unless it is installed upright. However, many existing 4-K GM cryocoolers are installed transversely on top of the magnets to allow maintenance servicing even in rooms with low ceilings. A pulse tube cryocooler cannot be installed on these magnets.

Fig. 3 Magnet with a 4-K GM cryocooler
(Cryocooler installed vertically, Siemens)

Recently, magnets with a 4-K GM cryocooler installed upright have been introduced so that the change to a pulse tube cryocooler can be made in the future. The change from 4-K GM cryocoolers to 4-K pulse tube cryocoolers will be possible provided the cost lowers and reliability is verified.

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Feature Articles : Refrigerating and Cooling Technology for Superconducting Apparatus
- View of Cooling Technology for Superconducting Magnetocardiographs -

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Application of cryocoolers to bio magnetic measuring instruments is being examined at present.

At an early stage, Daikin Industries delivered a magnetoencephalograph to Akita Brain Research Center, which used a cryocooler in place of liquid helium for cooling SQUID (superconducting quantum interference device). In this system, a signal processing was applied to remove noise caused by cryocooler vibration. However, recent magnetoencephalographs avoid use of cryocooler generating the system noise to detect more weak signal from the brain.

On the other hand, there are two directions in the development of magnetocardiographs. The first direction is for precision diagnosis to estimate irregular pats in arrhythmia and for measuring the feeble signals of fetus. For these measurements, a low-temperature SQUID having equal sensitivity to the magnetoencephlograph is necessary. The second direction is the development of simple magnetocardiographs for medical checkups and group medical checkups designed to prevent cardiac diseases. Hitachi has developed a multi-channel system that uses a high-temperature SQUID cooled by liquid nitrogen. This system is used in the clinical setting. Twente University has developed a high-temperature SQUID magnetocardiograph with one measurement point using a pulse tube cryocooler with small vibration. The application of the cryocooler for SQUID system is active especially for nondestructive test systems. Iwate University and Toyohashi University of Technology have announced their SQUID cryocooler cooling methods.

Systems for cryocooler cooling with a number of channels needed for mapping as in magnetocardiographs have yet not been realized. Problems when cryocoolers are used will be vibration, temperature control and distribution, time to arrive at the cooling temperature, and price. These problems will become more prominent when SQUID sensor arrays are directly cooled by a large cold head. However, failure of high-temperature SQUIDs, especially with heat cycles when temperature cycles repeat from the liquid nitrogen temperature to room temperature due to supply of liquid nitrogen can be resolved when a cryocooler is used. Additionally, the maintenance servicing problem of periodically transporting and replenishing liquid nitrogen can be eliminated almost entirely. However, the first problem of temperature cycles can be solved by placing SQUIDs in a vacuum chamber. The second problem relates to the trade-off between running costs including the cost of liquid nitrogen and maintenance servicing, and cryocooler system price and electricity charges. Therefore, the keys to cryocooler application to simple magnetocardiographs are low price and miniaturization of cryocoolers.

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Feature Articles : Systems Applying Superconducting Quantum Interference Devices (SQUIDs)

- Advances in SQUID Applied Systems -

Wide applications not only in medical treatment and diagnosis, but also in the industrial and scientific fields are expected for superconducting quantum interference devices (SQUIDs) that are ultrahigh-sensitivity magnetic sensors utilizing the quantization of a magnetic flux, which is one of the basic phenomena of superconductivity. Except for small-scale instruments such as magnetometers, multi-channel magnetoencephalograph systems, which used niobium low-temperature SQUIDs that were actively developed between the second half of the 1980s and first half of the 1990s, were the first SQUID-applied systems that were introduced to the market at full scale. Magnetoencephalograph systems are cooled by liquid helium and require a bulky magnetic shielding room, costing several hundred million yen for one system. In the past, about 20 imported and Japanese systems were installed in large hospitals and research organizations. As in Kohnan Hospital in Sendai, some of them are used for clinical purposes.

There were high expectations when high-temperature superconductivity was discovered that the discovery would greatly expand the market for simple systems using high-temperature SQUIDs that could be cooled by liquid nitrogen. Initially, however, the noise of SQUIDs was large, and high-performance systems were not built. Since then, thanks to advances in the thin-film technology and design technology, the noise of high-temperature SQUIDs has been reduced. In the second half of the 1990s, magnetic field resolution reached a level of 30 to 100 $fT/Hz^{1/2}$, which was several times higher compared to low-temperature SQUIDs, and fully acceptable for magnetocardiography. The development of the planar gradiometer (SQUID of linear differential type) has enabled use in some environmental magnetic fields. This has led to the search for applications other than in medical field, and demonstrations of applied systems are now being performed for nondestructive tests of structural materials, tests of foreign matter in foods and pharmaceuticals, tests of defects in semiconductor devices and LSIs and bio immunity diagnosis. An excellent cost performance ratio compared with that of conventional technology has to be demonstrated for commercialization and market entry. Many systems are expected to be launched within several years after good results are obtained.

The development of systems that use low-temperature SQUIDs is being actively undertaken. Recently, a 64-channel cardiac examination system has been sold. Attempts are also being made in the fields of magnetoencephalography examination and nondestructive inspection to implement high functions such as visualizing phenomena that cannot be accomplished by conventional systems. One scenario for expanding the market for SQUID-applied systems in the future is to enhance the performance of high-temperature SQUIDs to that of low-temperature SQUIDs and to develop a technology for low-cost manufacturing, to build simple and low cost systems.

(Keiichi Tanabe, Director, Division of Electronic Devices, SRL/ISTEC)

(Published in a Japanese version in the August 2005 issue of *Superconductivity Web 21*)

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Feature Articles : Systems Applying Superconducting Quantum Interference Devices (SQUIDs)
- Current Status of Magnetoencephalographs (MEG) -

Hisashi Kado
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Kanazawa Institute of Technology

MEGs that non-invasively measure fine magnetic fields caused by the nerve activities of the brain are one most successful examples of SQUID application. Multi-channel MEGs exceeding 100 observation points have been developed one after another, and more than 30 MEG systems are in operation at hospitals and research organizations of brain functions in Japan.

Since 1996, when a group of the Superconductivity Sensor Laboratory of Japan developed a 256-channel whole-head-type SQUID MEG, MEGs have increasingly become multi-channel and high density in sensor packaging. At present, a 275-channel system developed by CTF of Canada has the largest number of observation points among commercialized MEG systems that are installed in medical facilities. A system jointly developed by Kanazawa Institute of Technology and Yokogawa Electric Co. and installed at the University of Tokyo with 440 channels and 300 observation points features the largest number of observation points in the world as a system for research.

A new vector gradiometer has been developed as a SQUID sensor of MEGs. The conventional MEG measures only magnetic fields in normal directions only when surfaces of the brain are scanned. Additionally, the new sensor can simultaneously measure independent three orthogonal components containing components in the tangential directions, thereby allowing the determination of magnetic fields at one observation point as vectors. This allows as much magnetic field information as possible to be obtained from a limited observation region. The 440-channel system mentioned above has conventional axial gradiometers in 230 places and a vector gradiometers in 70 places. By using these vector gradiometers, a system exceeding 1000 channels can technically be built.

Diagnosis of epilepsy and presurgical brain function mapping using the MEG was included in the United States in January 2003, and in Japan in April 2004, as applicable under medical insurance. However, cost, the MEG has not become widespread as rapid as initially anticipated due to its high cost. One factor pushing up the initial cost is the magnetically shielded room to shield environmental magnetic field noise. The cost of liquid helium is also a barrier to ordinary hospitals in installing the MEG systems.

To increase the number of sensors is no longer great matter to promote popularization of MEG among hospitals and clinics. What is important for MEG system to become widespread will be to lower price, to enhance system reliability and to expand applications. For that purpose, we should give priority to improvement of system robustness, development of signal processing for auxiliary techniques such as noise reduction and a magnetic field source analysis technique, an active magnetic field shield technique, and improvement of the cryogenic system are also important.

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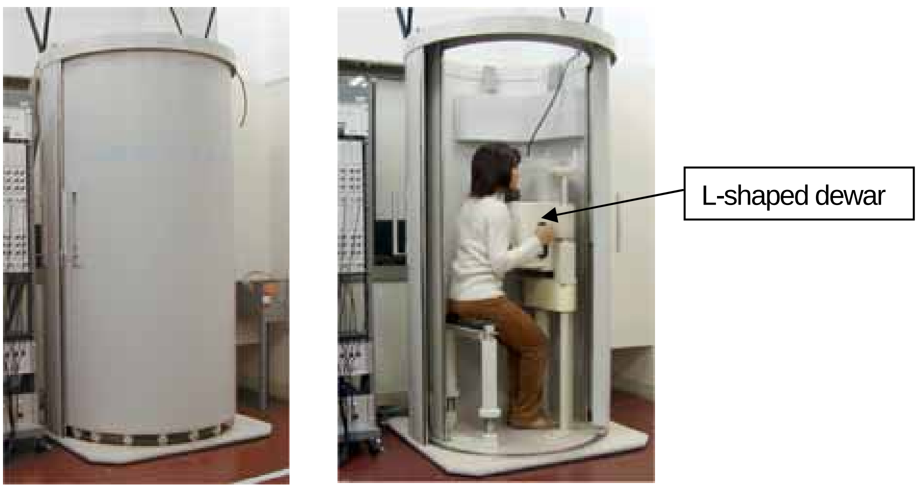
Feature Articles : Systems Applying Superconducting Quantum Interference Devices (SQUIDs)
- Development of Transportable Magnetocardiograph Using High-temperature Superconducting SQUID, Expansion to Medical Checkup Application by the Development of Compact Magnetic Shield -

Akihiko Kandori
Life Science Research Center
Central Research Laboratories, Hitachi, Ltd.

As part of a project to subsidize development costs for the commercialization of industrial technologies sponsored by the Ministry of Economy, Trade and Industry and New Energy and Industrial Technology Development Organization (NEDO), a compact and movable 16-channel high-temperature superconducting magnetocardiograph and a 51-channel high-temperature superconducting magnetocardiograph have been developed. The features of the technology for these magnetocardiographs are a compact magnetic shield room and multi-channel technology for high-sensitivity high-temperature superconducting SQUID sensors.

A full view of the 16-channel high-temperature superconducting magnetocardiograph is shown in Fig. 1. [1), 2)] A magnetocardiograph of an examinee can be taken by pressing the chest against an L-shaped dewar. The shield is vertical and its footprint is very small, about 1 m^2.



(a) External view (b) Interiors

Fig. 1 16-channel high-temperature superconducting magnetocardiograph

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The 51-channel high-temperature superconducting magnetocardiograph is shown in Fig. 2. [3), 4)] A high-temperature superconducting SQUID unit is structured monolithically on a bed of this magnetocardiograph. The sensor and heart can be aligned by operating the panel in the outside of the dome magnetic shield chamber so that the entire bed slides into the dome magnetic shield chamber to be ready for measurement. Mapping examinations of the cardiac electromotive force will be possible using this system.

As mentioned above, the high-temperature superconducting magnetocardiograph is a future form of magnetocardiographs that are expected to be widely used in applications such as group medical checkups. Many technologies gained in this development project will be utilized to build products.

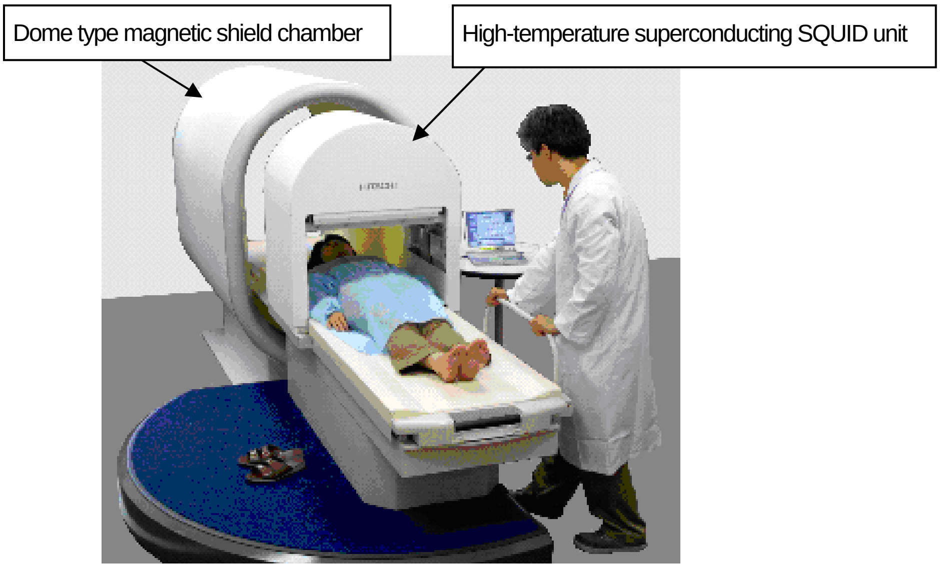

Fig. 2 51-channel high-temperature superconducting magnetocardiograph

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Feature Articles : Systems Applying Superconducting Quantum Interference Devices (SQUIDs)
- Traveling SQUID Nondestructive Testing System -

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Research and Development Center
Tohoku Electric Power Co., Inc.

SQUID sensors in conventional SQUID nondestructive testing (NDT) systems are fixed to achieve good protection against environmental magnetic noise, and these systems have been stationary to evaluate test samples by placing them on an x-y stage or by rotating them. Virtually, they cannot be used in NDTs of large test samples on site. Compared with this, we recently developed a 'traveling' SQUID-NDT system for application to a fixed object. The notable feature of the developed system is that the SQUID sensor itself moves or scans along the surfaces of the test sample in the ambient environment without the need for magnetic shielding. Using this system as a core technology, it will be technically feasible to evaluate a large object by installing SQUIDs on site.

A 'traveling' SQUID gradiometer(quasi-3rd-order), a portable cryostat, and noise cancellation procedures are the essence of the traveling SQUID-NDT system and are summarized as follows. (1) A traveling SQUID gradiometer that can suppress spatial magnetic noise generated by the movement of the SQUID sensor. (2) A portable cryostat to minimize vibration noise and to realize user-friendly operation. (3) A noise cancellation procedure is also developed to eliminate undesirable magnetic noise signals. The traveling SQUID gradiometer is a low-Tc SQUID gradiometer that contains two coplanar concentric second-order derivative coils connected in series and positioned counterclockwise to each other. Please see our current publications for more details of the traveling SQUID-NDT system.

In practical use, the shapes of the objects are not necessarily always flat. Based on the technology of the traveling SQUID-NDT system, a new system that is close to commercialization has been built to inspect curved-surface objects by utilizing a conventional articulated-type (6-axes) robot used in industry, to manipulate the SQUID sensor in 3D (three-dimensionally) to travel across an object. The figure shows the 3D traveling SQUID-NDT system (3D SQUID-NDT). A computer-aided geometrical interpolation method combined with a laser CCD displacement sensor was also developed to teach the 6-axes robot about the 3D (xyz) coordinates of the surface of the evaluated object.

Figure 3D traveling SQUID-NDT system

A stable supply of low-price, high-quality electric power to the customers is the basics of services even in competitive electricity markets. To meet this demand, higher safety and reliability of facilities are serious concerns in the electric power industry. Our target is to improve the SQUID-NDT system further including a practical database, to commercialize SQUID nondestructive inspection in maintenance and repair servicing of equipment and facilities in the electric power and other industries.

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Feature Articles : Systems Applying Superconducting Quantum Interference Devices (SQUIDs) - Highly Sensitive Immunity Test System -

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A magnetic immunity test system to detect at high sensitivity protein and other substances, which derive from diseases, needed in medical diagnosis is being developed. This method couples a test reagent (a magnetic marker antibody) identified using magnetic nanoparticles with an object substance (an antigen), and the magnetic signals emitted by the marker are measured to detect the type and quantity of the object substance. Using a SQUID sensor, feeble magnetic signals emitted by a marker can be measured, and immunity tests at extremely high sensitivity will be possible. The recently developed test system is shown in Fig. 1. [1] The reaction vessel is free of magnetic impurities and is in the shape of a disc capable of measuring 12 test samples. The SQUID is made of a high-temperature superconductor, and the distance between test samples and SQUID is short, 1.5 m, to enable the detection of magnetic signals emitted by the test samples at room temperature. Hitachi built the SQUID device and Inoac, the reaction vessel.

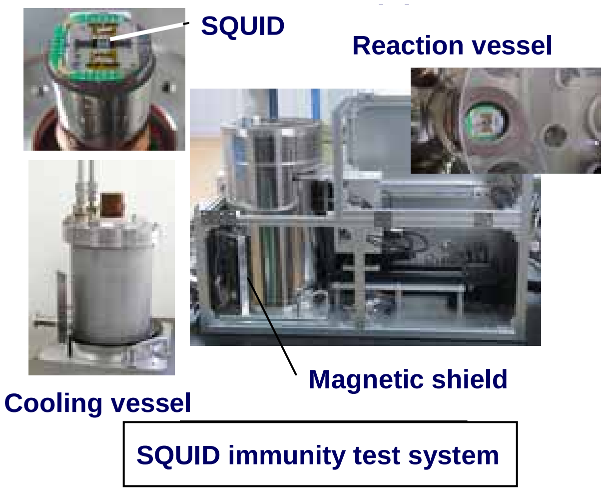

Fig. 1 SQUID immunity test system
(Jointly developed by Hitachi and Inoac)

An example of a measurement signal waveform is shown in Fig. 2(a). Rotating the reaction vessel measures 12 test samples. In the measurement, 100 averaging calculations are made, enabling high-sensitivity detection of 12 test samples in a measurement time of 400 seconds. Fig. 2(b) shows the detection of a protein called human IgE related to allergy. The axis of abscissas plots the weight of IgE in w(pg) and the axis of ordinates, a flux signal Φ_s (mΦ_o) detected by a SQUID. In this experiment, IgE down to 0.3pg was detected, and this result is 100 times more sensitive compared to conventional techniques. The solid line in the diagram plots the analysis result with the absorption model and well matches the experiment results.

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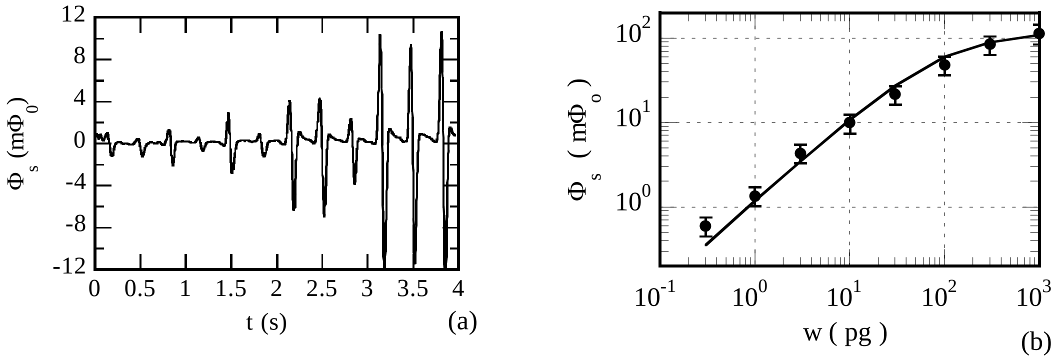

Fig. 2 (a) Waveform of measured signal. Reaction vessel is rotated to measure 12 test samples. (b) Relationship between weight w of antigen (IgE) obtained in the immunity test and signal flux Φ_s. The solid line shows the analysis results.

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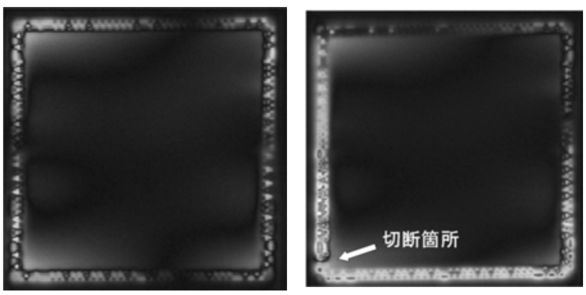
Feature Articles : Systems Applying Superconducting Quantum Interference Devices (SQUIDs)
- Development of a Scanning Laser SQUID Microscope for LSI Inspection and Failure Analysis - localization of Logic-LSI metal-line open sites -

Kiyoshi Nikawa
Test Analysis Technology Development Division
Technology Foundation Development Operations Unit
NEC Electronics Corporation

Designed to efficiently inspect LSI chips and localize their defects or failure sites in the manufacturing process and after manufacturing, NEC Electronics has developed a new analysis system (scanning laser superconducting quantum interference device [SQUID] microscope) combining a laser and a SQUID and is studying its specific application methods. The scanning laser SQUID microscope detects magnetic fields caused by a photo-current generated when a laser beam is radiated onto an IC chip using a SQUID magnetometer, which is a magnetic sensor with ultrahigh sensitivity. Scanning of the IC chip produces a magnetic field intensity image and magnetic field phase image.

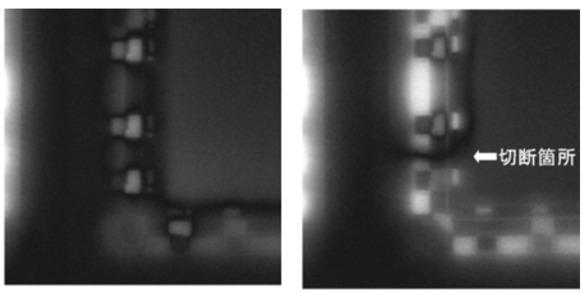
A recent experiment has shown that the localization of failure siles by L-SQ that has been considered difficult in the past can be accomplished to some extent. The sample used in the recent experiment was a logic LSI with a gate length of a 53-nm level (so-called 90-nm node).

The melal line was cut by FIB, and the differences in scanning laser SQUID microscope images before and after cutting were studied using the intensity and phase images. The intensity images before and after cutting are shown in Figs. 1 and 2. Fig. 1 shows the results of the observation of the entire chip and Fig. 2, the results of observation around the cut segments. Clear intensity variations corresponding to the cut segments can be observed when the images before and after cutting are compared.



(a) Before cutting (b) After cutting

Fig. 1 Comparison of intensity images before and after metal line cutting. Observation of the entire chip (5-mm square)



(a) Before cutting (b) After cutting

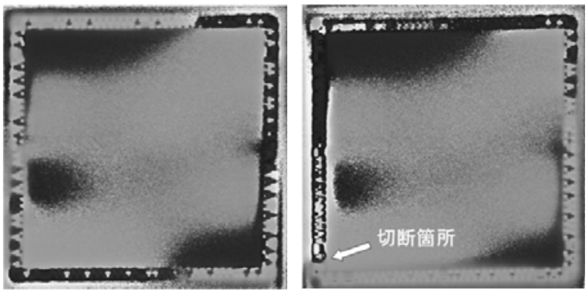
Fig. 2 Comparison of the intensity images before and after metal line cutting. Observation of the area around the cut segment (1-mm square)

Fall, 2005 Date of Issue: October 17, 2005

Superconductivity
Superconductivity Web21

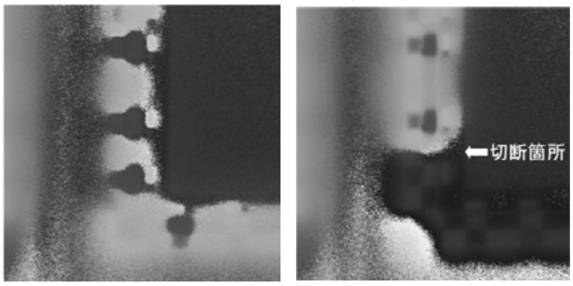
Published by International Superconductivity Technology Center
5-34-3, Shimbashi, Minato-ku, Tokyo 105-0004, Japan Tel: 03-3431-4002, Fax: 03-3431-4044

As shown in Figs. 3 and 4, behavior is slightly different with the phase images, and phase inversion can be observed at the cut segments after cutting.



(a) Before cutting (b) After cutting

Fig. 3 Comparison of the phase images before and after metal line cutting. Observation of the entire chip (5-mm square)



(a) Before cutting (b) After cutting

Fig. 4 Comparison of the phase images before and after metal line cutting. Observation of the area around the cut segment (1-mm square)

(Published in a Japanese version in the August 2005 issue of *Superconductivity Web 21*)

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Feature Articles : Systems Applying Superconducting Quantum Interference Devices (SQUIDs)
- Development of Inclusion in Detection System for Foods and Pharmaceuticals -

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The food processing factories manufacture foods with minute care, but accidents of foreign matter mixed in foods sometimes occur. Losses including product recovery cost and lost profits (profits calculated accruable had there been no accident) run to several billions to several tens of billions of yen for large food processing manufacturers. Prevention of these accidents is a major concern for them. At present, inclusion of foreign matter is detected by eddy-current, X-ray and other test methods. However, the sensitivity of these methods is not adequate, and the stainless steel mesh wires (0.3 to 0.5 mm in diameter) of the strainers (filters) used in the manufacturing process and other foreign matter that have recently become topics cannot be detected due to insufficient sensitivity performance. The SQUID sensor system is an epochal method that replaces conventional methods. This method magnetizes test samples using a magnet and measures residual magnetization by a high-sensitivity magnetic sensor. The method is immune to the effects of moisture and temperature and is hardly susceptible to the effects of packaging materials such as aluminum foil. No radiation (X-ray) dose problems are caused. Subsidized by an urban area industry-academia-government collaboration promotion project for the Toyohashi area sponsored by Ministry of Education, Culture, Sports, Science and Technology for 2002 - 2004, Toyohashi University of Technology developed a test system for the detection of foreign matter in foods and pharmaceuticals and is selling the system. (http://www.aftweb.co.jp/index.htm)

A high-performance magnetic shield and electromagnetic shield were the key elements in system development, and an adequate study was conducted. A full view of the system used in the field is shown in Fig. 1. The shields are located inside the stainless steel shell. The system specifications are as follows.

Fig. 1 Product appearance of foreign matter test system

- Measurement magnetic damping ratio: 0.14% (1/732) (DC, vertical direction)
- System dimensions (mm): 1500 L x 477 W x 1445 H
- Dimensions of effective aperture (mm): 200 W x 80 H
- Conveyor speed: 1 - 100 m/min
- Shell: All stainless steel (HACCP compatible)

- Automatic nitrogen feeder installed
- Number of sensors: 3, high-temperature superconducting SQUIDs
- Sensor drive circuit: Modulated FLL system
- Detection performance: Stainless steel or steel balls 0.3 mm in diameter 30 to 50 mm distant detected

(The values are for general information purposes.)

Almost twenty years have passed since the discovery of high-temperature superconductivity. A foreign matter test system using high-temperature superconducting SQUIDs has finally been developed as a product. It is hoped that this system will be put into operation in various places to prevent mixing of foreign matter. Lastly, the author thanks Dr. Shuichi Suzuki of Advance Food Technology, Dr. Tatsuoki Nagaishi of Sumitomo Electric Hightechs, Dr. Noriyoshi Fujita of Toyohashi University of Technology and those involved in the development of the system for their cooperation.

(Published in a Japanese version in the August 2005 issue of *Superconductivity Web 21*)

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Standardization Activities

Topics in July

- One IEC standard issued -

The International Electrotechnical Commission (IEC) on April 21 2005 issued the following standard for test methods on superconductivity as the 13th standard.

- Standard No.: IEC 61788-9 (2005-04)
- Standard title: Superconductivity - Part 9: Measurements for bulk high-temperature superconductors - Trapped flux density of large grain oxide superconductors
- Standard revision time: 2008
- Overview of standard

The standard specifies a method of testing trapped flux densities of bulk high-temperature superconductors. This international standard can be applied to large crystal discs, and rectangular and hexagonal bulk oxide superconductors. The trapped flux density is tested within a temperature range of 4.2 K to 90 K. Reporting of test results at liquid nitrogen temperature is required by the standard.

- Brief history of standard deliberation

The draft of this standard was proposed in 2000 by VAMAS and Japan National Committee. An international conference in Boulder, United States, held in March 2000 approved for WG10 to prepare the draft as a normative document under a new business item. In December 2000, a committee draft CD was submitted. In 2001, a committee draft for voting CDV was submitted. In 2002, CDV was resubmitted. In 2004, Final Draft International Standard FDIS was submitted. In April 2005, International Standard IS was issued.

- 2005 Steering Committee Meeting for the IEC/TC90 Superconductivity Committee -

The 18th Steering Committee meeting of the IEC/TC90 Superconductivity Committee in Japan (Chairperson, Shigeki Saito, Senior Managing Director of ISTEC) was held at the Shimbashi Annex Meeting Room on June 8, 2005.

The meeting discussed the draft 2004 business report, draft 2004 financial statements, draft 2005 business plan and draft 2005 budget. The documents were approved. Prominent projects taken up in 2004 were “Study on the Standardization of the Technical Base of Superconducting Power Equipment” sponsored by the Ministry of Economy, Trade and Industry and “2004 Superconductivity Standardization Project” sponsored by the Institute of Electrical Engineers of Japan.

The ultimate purpose of these standardization projects is to expand their results into international standards by obtaining the consensus of Japan and other countries. A prerequisite to the standardization of superconductivity products is obtaining the consensus of those concerned with superconductivity inside and outside Japan. The importance of conducting step-by-step, minute activities has been recognized.

(Yasuzo Tanaka, Director, Standardization Department, ISTEC)

(Published in a Japanese version in the July 2005 issue of *Superconductivity Web 21*)

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