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10th IEC/TC90 (Superconductivity) International Conference Held in Kyoto

The 10th International Conference of IEC/TC90 (90th Technical Committee of International Electrotechnical Commission - Superconductivity) was held from June 6 to 8, 2006, at the Centennial Clock Tower Memorial Hall of Kyoto University attended by 47 representatives in total (1 person from the U. S. A., 4 from Germany, 8 from China, 5 from Korea and 29 from Japan). Two new projects were approved and the conference ended successfully.

The international conference of IEC/TC90 is held in Asia, Europe and the United States every 18 to 24 months on a rotation basis. The first conference was held in Tokyo in 1990 and the 10th conference was held in Kyoto.

The conference consisted of an ad hoc group meeting (June 6 and 7), working group meeting (June 6 and 7), plenary session (June 8) and social event (June 7). The conference meetings and events were held in accordance with the IEC conference manual.

Chairman Dr. Loren F. Goodrich declared the opening of the conference at the plenary session held on June 8. This was followed by a welcome speech and message of expectations for IEC/TC90 activities by Mr. Makoto Yokota, director, Standards Development and Planning Division, Industrial Science and Technology Policy and Environment Bureau, Ministry of Economy, Trade and Industry. An extension of the term of office of the chairman from April 1, 2006, to March 31, 2009, was confirmed. The groups briefed their activities and confirmed the deliberations made. Lastly, the venue for the 11th International Conference of IEC/TC90 was deliberated. It was decided to select a venue later with a lapse of two years after the current meeting on a rotation basis.

Mr. Makoto Yokota, Director, Standards Development and Planning Division, Ministry of Economy, Trade and Industry, making the welcome speech.

Dr. Loren F. Goodrich opening the conference.

The meeting in Kyoto deliberated the following topics.

1) Ad hoc Group 1 (Current leads)

Prof. Kozo Osamura, the rapporteur, reported the activities conducted since the Argonne conference and future procedures.

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It was approved by agreement among four countries (Germany, China, Korea and Japan) that all kinds of current leads for power supply applied to superconducting equipment should be within the applicable scope, that it should be advanced to general requirements standardization which includes definition of related terms and major characteristic test items and simultaneously with new work item proposal (NWIP), to move up to formal procedures to establish a new WG. Ad hoc Group 1 would continue to function until a formal WG is inaugurated.

2) Ad hoc Group 2 (uncertainty)

Dr. L. F. Goodrich, the rapporteur, reported the activities conducted since the Argonne conference and future procedures. The term "uncertainty" was used at about 40% of the other TCs of IEC. The five participant countries recognized that it was time for TC90 also to use it. However, it was also confirmed that the application of "uncertainty" by TC90 would require the following considerations. (1) To try beginning a stage (WG4) before WG5 (Nb-Ti wire room temperature pull test method and CDV stage) which is currently being maintained and FDIS. (2) Related terms will quote GUM (Guide to the Expression of Uncertainty in Measurement). Dr. L. F. Goodrich, the rapporteur, will present a specimen. (3) The conveners were instructed to give sufficient consideration, such as describing in the remarks column a match with "accuracy," when producers and manufacturing organizations issue specifications to avoid confusion in the transitory period. Ad hoc Group 2 will be disbanded when specimens of related terms and caution items are developed in two or three months.

3) Maintenance of current IEC standards and future maintenance

◊ A proposal was made on maintenance of WG1 (superconductivity glossary) and was approved. Prof. Teruo Matsushita was recommended as a new convener and was approved.

◊ All WG2 (Nb-Ti wire Ic test method), WG7 (Nb_3Sn wire Ic test method), WG8 (surface resistance test method) and WG11 (Tc test method) are in the FDIS stage. It was approved to upgrade them to the IS stage (Ed.2) in accordance with the standard schedule. The result of FDIS voting was approved for WG3 (Bi wire Ic test method) and WG3 will move to IS. WG4 (Nb-Ti wire RRR test method) will move to the FDIS stage in August and will incorporate "uncertainty." Standards of WG2, WG3, WG7, WG8 and WG11 are already in the FDIS edited stage and have missed the opportunity of incorporating "uncertainty." It was confirmed that the incorporation of "uncertainty" will be taken up in Ed.3 and subsequent editions.

◊ A proposal was made to start maintenance of WG4 (Nb_3Sn RRR test method) and was approved.

◊ It was confirmed that WG5 (Nb-Ti wire room temperature tensile test method) would be circulated as a CDV draft taking "uncertainty" into consideration.

◊ Comment confirmation in DC stage was confirmed completed for WG9 (NbTi wire AC loss test method). Moving of two standards to the MCR issue stage was approved.

Plenary session

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4) Reporting on activities of countries and organizations

◊ China reported that it was adopting a policy to enhance standardization and that superconductivity was overviewed by SAC/TC265 chaired by Mr. Yang Qiaysheng (CAS). China reported that standardization activities on superconductivity were undertaken in seven categories, namely, Jc, AC loss, levitational force, RRR, Tc, glossary and so on.

◊ Germany reported that superconductivity standardization was taken up by GNC/K184 "Supraleiter" chaired by Mr. Helmut Krauth and vice-chaired by Mr. Manfred Thoener. Germany reported maintenance and other standardization activities classified into eleven IEC/WGs.

◊ Japan presented an overview of standardization activities. In addition to standardization of new measurement methods and maintenance activities of existing international standards, Japan made interim reports on product standardization activities related to superconducting generator conductors, SMES (superconducting magnetic energy storage) conductors, superconducting current leads and other superconducting equipment. Japan also made an interim report on standardization activities in superconducting electronics related to microwave and Josephson junction devices.

◊ Korea reported that KNC was established in 1995, to which experts are dispatched interfacing with 11 IEC/WGs. Korea reported on national projects (KSTAR, ITER and power application NFP) and on future standardization (magnetization method Tc, surface resistance, current leads, irreversible magnetic field). Prof. S. Y. Lee presented a draft for a surface resistance test method for superthin films and was unanimously approved to move it to formal NWIP procedure.

◊ VAMAS

VAMAS made an interim report on basic standardization centering on test methods by four WGs. A draft reflecting the results of RRT was presented on standardization of a room temperature tensile test method of Nb_3Sn wires.

5) Revised standardization strategy

◊ The member countries were requested to review the 2004 Superconductivity Standardization Strategy Paper SMB/2935/R.

◊ The member countries register their experts in WGs through IEC/Web. The participant countries were requested to update their information. International Secretary Sato was requested to notify absent P-member countries to update their information.

6) New work item proposal (NWIP)

◊ It was approved that standardization of general requirements on definition and characteristic test methods of current leads should be moved up to formal procedures as a new work item proposal (NWIP) and to a proposal to establish a new WG simultaneously.

◊ It was approved to move up standardization of a surface resistance test method for superthin films in WG8 (surface resistance test method) to a formal NWIP.

Social event

(Yasuzo Tanaka, Director, Standardization Department, ISTEC)

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Feature Articles:
Refrigeration and Cooling Technologies for Superconducting Equipment - Current Status and View of Refrigeration and Cooling Technologies for Superconducting Systems -

Yasuharu Kamioka, Corporate Officer, Deputy General Manager
Development and Engineering Division
Taiyo Nippon Sanso Corporation

Recently, superconducting system is approaching commercialization and refrigeration and cooling technology tuned to be very important for the commercialization. Refrigeration device used in superconducting system includes G-M, stirling, pulse tube cooler and turbine Brayton cycle refrigeration machines. There are cryo-coolers that can be used in superconducting system to be commercialized. However, many of them have been developed for cryo-pumps, MRI coolers, and experimental equipments. The development of refrigeration machines that are satisfactory to superconducting system is necessary not only in terms of shape, dimensions, but also cooling temperature, cooling capacity, efficiency and other performance parameters.

The cooling capacity required for a high-temperature superconducting system is several watts to several kilo watts at from 40 to 70K. The efficiency of refrigeration machines decreases the lower the temperature is and a larger refrigeration machine is needed for lower temperature even though the cooling capacity is the same. Due to market constraints and regulation by the High Pressure Gas Control Law, refrigeration machines of 1kW or higher at 70K are not sold in Japan. Refrigeration machines of 5 to 6kW at 65K will be needed for large superconducting system and these refrigeration machines have not been manufactured.

However, refrigeration machines of less than 1kW in cooling capacity at 70K have been manufactured and these machines can be used in superconducting system relatively easily. A series of modifications and improvements will be needed to supply superconducting system to the general market. On the other hand, refrigeration machines of 1kW or higher has constraints such as foregoing reason and the capacities of G-M, stirling and pulse tube cooler (which are generally used as cooling machines of this class) cannot be increased for the technical reason. Because of this, refrigeration machines of other types are needed to be developed. One candidate is the turbine Brayton cycle refrigeration machines. These refrigeration machines larger than several ten kW in capacity have been manufactured for a cryogenic air separation plant, a helium liquefaction plant and other uses. However, machines with a capacity of several kW at about 70K have not been manufactured. Technology development for miniaturization is needed for components such as turbines and heat exchangers.

Thus viewed, there are cooling machines of two regions, namely, G-M, stirling and pulse tube cooling machines, whose operating principles are basically the same as those of small cooling machines of less than 1kW in capacity, and turbine Brayton cycle cooling machines of more than 1kW in capacity. Additionally, heat exchangers, subcooled liquid nitrogen circulating devices and other cooling devices that thermally connect cooling machines and superconducting system will be important components in actual system cooling.

A High-temperature superconducting system is entering a commercialization phase at present. Before it can be widely accepted in society, the rapid development of refrigeration and cooling systems with dimensions, shape, temperature, performance, efficiency, reliability and high maintainability suitable for commercialization is necessary.

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Feature Articles:
Refrigeration and Cooling Technologies for Superconducting Equipment
- Development of 0.1W 4K Compact GM Refrigerating Machine -

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Engineering Department
Precision Equipment Division
Sumitomo Heavy Industries, Ltd.

1. Preface

As scientific equipment, medical apparatuses, semiconductor manufacturing systems and equipment and other systems become higher in precision and sensitivity, low temperature environments often become essential as in cooling of samples and detectors. Rather than large equipment and systems, compact refrigerating machines that can be handled easily are needed for equipment and systems for research and experimental purposes such as physical property measurement, for which universities and research organizations are principal customers. To meet these needs, Sumitomo Heavy Industries developed a 0.1W 4KGM refrigerating machine.

2. Principal Specification of Compact 0.1W 4K GM Refrigerating Machine

This refrigerating machine has the smallest refrigeration capacity among the 4KGM refrigerating machines. However, it is compact, light and consumes minimum power. The machine not only attains 4K, but also is powered by single-phase 100V AC and is an energy saving, compact 4K refrigerating machine that can be plugged into an AC plug socket in laboratories and offices.

1) Refrigerating machine unit type: RDK-101D, compressor unit type: CNA-11B
2) Input power: AC 100V single phase
Power saving (50/60Hz): Steady state 1.2/1.3kW, maximum 1.3/1.5kW
3) Compact, lightweight: 7.2kg, 442 x 226 x 130mm (refrigerating machine unit)
4) Refrigeration capacity: Single stage 60K 3W, dual stages 0.1W or more at 4.2K
Minimum ultimate temperature: 2.5K
5) Can be installed in all directions
6) UL and CE compatible

The working fluid is a helium gas. The refrigerating machine consists of a helium compressor unit, refrigerating machine unit, flexible hose and refrigerating machine power cable. The compressor unit is air cooled for convenience in operating it. The machine is powered by AC 100V single phase and its power consumption is low, equal to operating a dryer. It can be used easily like other measuring instruments if caution is exercised regarding the electric power capacity on the primary side.

3. System Characteristics

The refrigeration capacity is the capacity to maintain the temperature below a specified temperature when a thermal load is applied to the cooling stage of the refrigerating machine being operated. The 4K refrigerating machines manufactured by Sumitomo Heavy Industries maintain a stable 4K-level refrigeration capacity through the special construction of its cold storage unit and optimization of its cold storage material. The first stage of the prototype failed to attain the specified refrigeration capacity (about 2W at 60K). However, the refrigeration capacity specification is accomplished by improving the cold storage material. Lowering of the refrigeration capacity when the refrigerating machine attitude is varied one turn is kept low, 5% with Stage 1 and 15% with Stage 2, by employing a special construction with the second stage cold storage unit, allowing installation in all directions.

In electrical characteristics, the inrush current was 40A or less and maximum current during cooling down, 15A or less, verifying that the machine can be connected to AC 100V single phase. Power consumption is 1.5kW maximum and is less than 1/5 that of a 1W 4KGM machine, attaining a 4K temperature environment with low power consumption.

Refrigerating machine unit RDK-101D

Compressor unit CNA-11B

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Feature Articles:
Refrigeration and Cooling Technologies for Superconducting Equipment
- Development of 2W Compact Pulse Tube Refrigerating Machine -

Yukio Yasukawa
Equipment Technology Laboratory
Fuji Electric Advanced Technology Co., Ltd.

Compact pulse tube refrigerating machines are free of moving parts and feature low vibration and high reliability as expansion machines. They are attracting attention as a substitute for high-sensitivity detectors that have been cooled by liquid nitrogen.

Fuji Electric Systems and Fuji Electric Advanced Technology have developed a compact sterling-type pulse tube refrigerating machine with refrigeration output of a 2W class (Fig. 1). The machine was developed incorporating “low vibration” and “high reliability” which were the features of the compact sterling-type pulse tube refrigerating machine, aiming at achieving the compactness and ease of handling of a sterling refrigerating machine. The expansion unit has a cooling unit at its end by connecting a cold storage unit and pulse tube in “U” shape. A buffer tank, a component in the phase control mechanism, is integrated with the compressor, achieving a monolithic construction as a refrigerating machine. This affords ease of handling equal to that of a sterling refrigerating machine in mounting of material to be cooled and in carrying and installing the refrigerating machine. The refrigeration capacity is 2.5 and 3.5W at cooling-end temperature of 70 and 80K, respectively. (Power consumption 100W operation, 25°C ambient temperature)

Vibration is not caused at the low-temperature end because no moving parts are installed. However, it is important for the compressor to achieve low vibration equal to the level of vibration in cooling by liquid nitrogen. Fundamental vibration is canceled by installing opposite pistons in the compressor. The flexure bearings supporting the pistons have a higher linearity in piston operation by increasing their radial rigidity. A reduced imbalance of the unbalance force that is caused by a constitutional unbalance between two pistons has also contributed to attaining very low vibration. The piston unit is fitted using an automatic positioning device to build a clearance seal perfectly without any sliding. Through these techniques, the vibration level at the low temperature side can be confined to 1µm or less and on the fixed flange side, 0.1µm or less. Continuous operation of 40,000 hours at high reliability has been demonstrated.

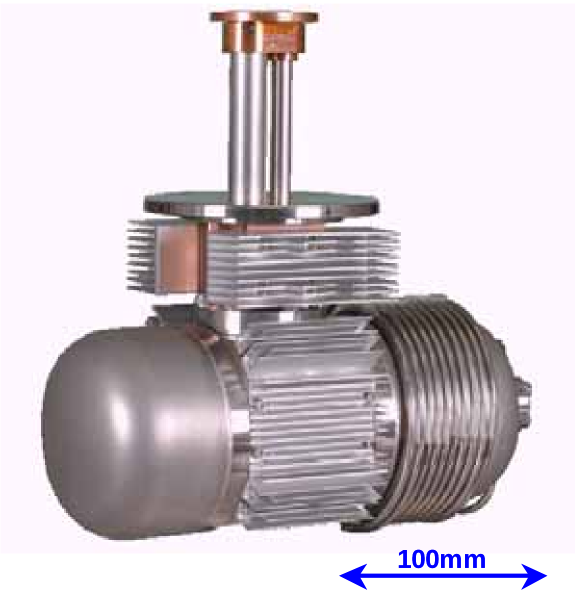

Fig. 1 2W compact pulse tube refrigerating machine

One problem with the pulse tube refrigerating machine is the low performance caused by the installation direction. The performance difference when the low-temperature part is installed downward and upward is 3% or less at 77K, which is

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considered entirely immune to problems in actual use. (Fig. 2) A separate refrigerating machine will be put on the market in the future, built by separating the low temperature part from the compressor and connecting it using a flexible connecting tube for use in manufacturing ultrahigh sensitivity detectors, with which impacts of electromagnetic noise caused by the compressor present a problem.

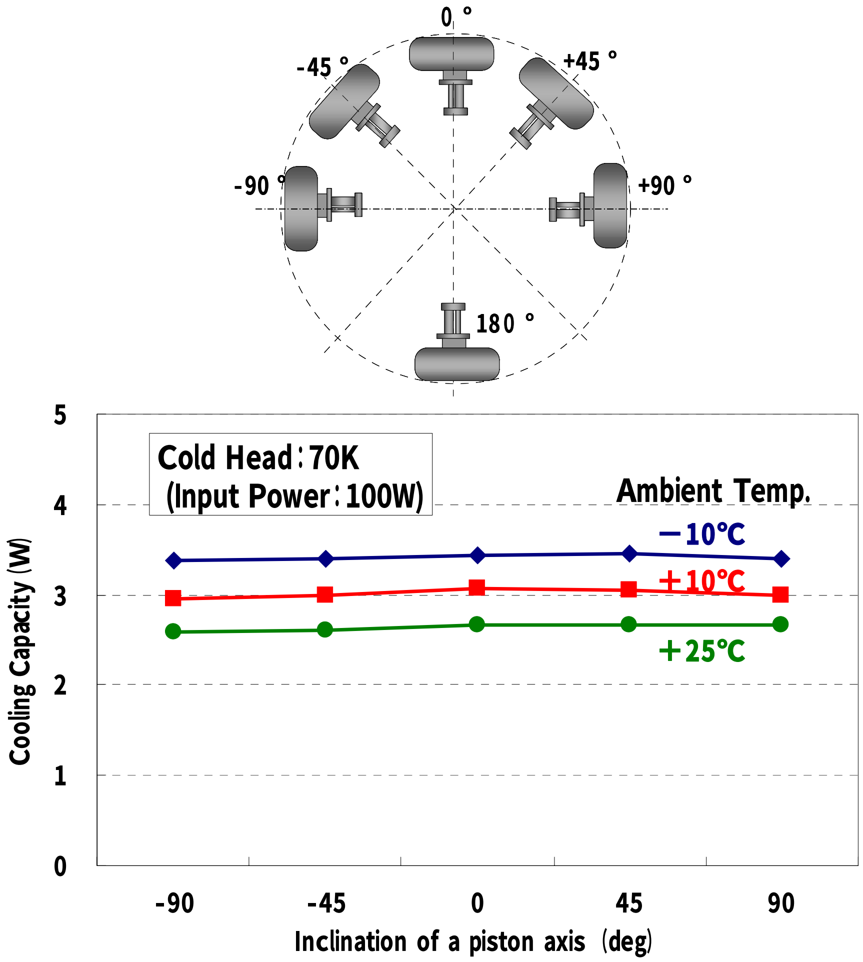

Fig. 2 Impact of cooling capacity by installation direction

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Feature Articles:
Refrigeration and Cooling Technologies for Superconducting Equipment – Development of 300W Large Stirling Type Pulse Tube Cryocooler –

Nobuo Okumura
Group Manager
Vacuum and Cryogenic Group, Energy System Department
AISIN SEIKI CO., LTD.

A Stirling-type pulse tube cryocooler is being developed aiming at achieving a long lifetime and high efficiency. One of the characteristics of this cryocooler is an integrated configuration of a compressor that has no wearing part and a pulse tube cold head that has no moving part. This cryocooler has no wearing part and few sources of gas pollution, inherently, affording far greater reliability than its same type predecessor. Aisin Seiki has completed an endurance test of more than 50,000 hours using a compact Stirling-type pulse tube cryocooler of model SPR-05, which has been sold since 1997 as a cryocooler used for superconducting filters and radiation detectors.

The 300W large Stirling type pulse tube cryocooler now being developed is intended for incorporation in the Superconducting Magnetic Energy Storage System (SMES). This Cryocooler is mainly composed of three components, a compressor, pulse tube cold head and phase shifter. The compressor uses clearance seal type piston supported by flexure bearings, and is expected long lifetime because of no wearing parts in it. The phase shifter with neck tubes realizes the system as the so-called third-generation pulse tube cryocooler, and contributes to a high efficiency of this cryocooler.

One of the largest feature of this Stirling type pulse tube cryocooler is dual cylinder construction, two regenerators and two pulse tubes with one cold head. This means as one compressor drives two cryocoolers. This dual cylinder system is mainly designed for controlling less dispersions of gas flow in the regenerator and pulse tubes than usual construction of one cylinder. If one cylinder construction is adopted, a regenerator and pulse tube become too thick to obtain the required PV work (expansion work), and this construction induces gas flow disturbing and lowering of cryocooler performance. This prevention of a dual cylinder construction make the Stirling type pulse tube cryocooler fulfilled SMES system requirements.

This Stirling type cryocooler has accomplished cooling performance of 300W at 77K with power consumption of 9kW.

Specification (March 2006)	
Refrigeration capacity	300W at 77K
Power consumption	9kW or less (200V AC, 3 phases)
External dimensions mm	1200 width x 700 depth x 1600 height

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Feature Articles:

Refrigeration and Cooling Technologies for Superconducting Equipment - View of Slush Fluid Technology as a Refrigerant -

Katsuhide Ohira
Professor
Institute of Fluid Science
Tohoku University

"Slush" is a two-phase (solid-liquid) single-component cryogenic fluid containing solid particles (about 1mm in size) in liquid. Technology development of slush hydrogen and slush nitrogen is carried out from practical aspects. [1] Slush hydrogen (temperature 14K) at solid mass ratio (solid fraction) of 50wt% increases about 16% in density compared with liquid hydrogen (temperature 20K) and its cryogenic heat capacity increases about 18% until it evaporates and becomes gas at 20K. Similarly, in the case of slush nitrogen (temperature 63K), density increases about 16% and the cryogenic heat capacity increases about 22%. Utilizing these characteristics, if slush nitrogen is used as the refrigerant of a high-temperature superconducting material, higher performance of wire can be expected compared with cooling by liquid nitrogen (temperature 77K) and an advantage of an increase in heat capacity against penetration heat from ambient temperature, quenching and other generations of heat can be expected. The spreading of polymer electrolyte fuel cells (PEFCs) has already put into practical use the technology of transporting hydrogen as a fuel by lorries in the form of liquid hydrogen and storing it in car-borne tanks of fuel cell vehicles. When more fuel cells are installed and more superconducting equipment that uses metallic high temperature superconducting materials (MgB_2) is used, the use of slush hydrogen as a refrigerant of superconducting power transmission, superconducting magnetic energy storage equipment and other equipment can be expected if slush hydrogen is used in place of gaseous hydrogen and liquid hydrogen as a fuel of fuel cells. When hydrogen in the form of slush hydrogen is transported and stored using pipelines as illustrated in Fig. 1, for example, superconducting power transmission using metallic high temperature superconducting materials (MgB_2) will also become feasible and the synergetic effect of simultaneously transporting a fuel for fuel cells and power can be expected. In short-distance power transportation, phase change of slush hydrogen

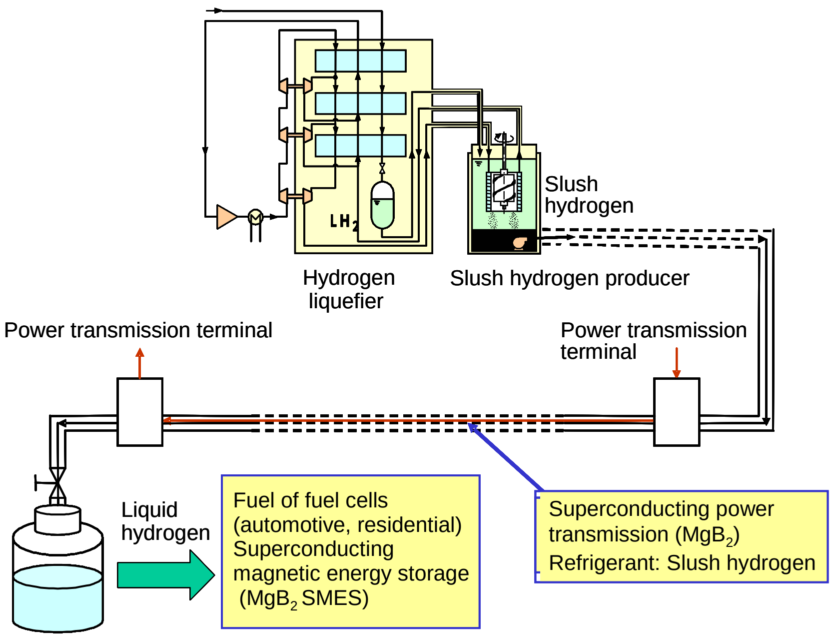

Fig. 1 Synergetic effect of combination of slush hydrogen and superconducting equipment

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from solid-liquid to liquid-gas two-phase state by penetration heat or other heat to pipe can be prevented, thereby mitigating undesirable phenomena for superconducting materials such as temperature oscillations of refrigerant, even though this depends on the quantity to be transported.

When solid-liquid two phase fluids are transported by pipelines as illustrated in Fig. 1, normally, pressure losses during flowing inside the pipe increase and an increase in pump drive power comes into question. A flow test of slush nitrogen in a pipe (15mm inner diameter) is currently conducted by the author and the pressure loss characteristics are obtained as shown in Fig. 2. The pressure loss coefficient (λ) decreases with an increase in Reynolds number (*Re*) and the pressure loss coefficient tends to become equal (solid line) to or smaller than that of a liquid (dotted line) in a practical region ($Re > 10^5$). A similar report has also been submitted on slush hydrogen, suggesting that hydrogen can be transported efficiently and the cooling temperature of superconducting materials can also be lowered.

Compared with liquid helium, slush hydrogen has good characteristics as a refrigerant in the aspects of required power for production and latent heat of evaporation, and expectations are placed on the development of commercialization technologies such as the acquisition of experimental data on physical properties and implementation of design techniques for equipment. More information on density meters, mass flow meters and characteristics of nucleate pool boiling heat transfer is available in the referenced literature. [1), 2)]

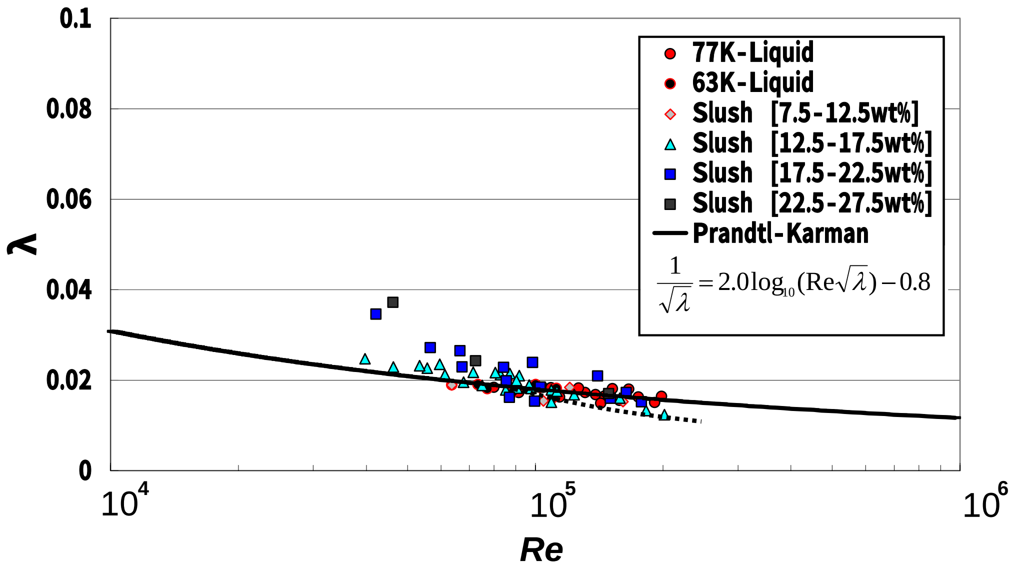

Fig. 2 Reynolds number (*Re*) and pressure loss coefficient (λ) when slush nitrogen flows in a pipe

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Feature Article: Forum on Superconductivity Technology Trends 2006

On Monday, May 29, 2006, ISTEC held a forum on superconductivity technology trends titled "New Evolution of Applied Superconductivity Technology: Age of Competition - Superconductivity Development at Turning Point" at the Toshi Center Hotel in Tokyo. Approximately 250 persons participated including those from industry, academia, government, the press and general public. Results challenges and trends in superconductivity technology development aiming at industrialization were reported and lively discussions took place.

Yuuko Yasunaga, Director, Research and Development Division, Industrial Science and Technology Policy and Environment Bureau, Ministry of Economy, Trade and Industry, and Yukao Tanaka, Director, New Energy Technology Development Department, New Energy and Industrial Technology Development Organization (NEDO), delivered congratulatory messages. Results of research and development reported at the meeting gave the impression that the superconductivity technology was fast approaching commercialization. As one of the key technologies in the 21st century, the direction for the superconductivity technology in the medium to long range was discussed using a technology strategy map. New technologies were expected to create new business ventures.

Shoji Tanaka, Director General, Superconductivity Research Laboratory, delivering keynote lecture.

In a keynote lecture titled "Superconductivity Entering the Practical Phase in 2006, " Shoji Tanaka, Director General, Superconductivity Research Laboratory (SRL), stated that the superconductivity technology has achieved great results overcoming various technical difficulties now that the technology was entering its 20th anniversary after the discovery of high-temperature superconductivity. Tanaka indicated that a future image of the technology toward 2010 to 2020 was steadily unfolding thanks to the development of practical equipment and application to new spheres was more visible such as the environmental and medical fields in addition to energy saving and resource saving.

Koichi Nakao, Acting Director, Division of Material Science & Physics, SRL, reported on the development of a non-contact measuring method of long wires and cables and that measurement results were fed back to wire development to expedite the development work.

Izumi Hirabayashi, Director, Bulk Superconductor Laboratory, SRL, reported on discovery of a new material (Gd210) from analysis of a sample obtained in a space experiment. Hirabayashi introduced application cases to various industries through the manufacture of large high performance bulk materials by a new synthesis method using the new material, through significant improvement in the characteristics of trapped magnetic fields thanks to recent technology development and through improved mechanical strength by impregnation of a resin.

Titled "NMR Application of Bulk Superconductor," Takashi Nakamura, The Institute of Physical and Chemical Research (RIKEN), reported the development of NMR equipment using bulk superconductors. Nakamura stated that the technology could be applied to various fields for equipment miniaturization through high magnetic fields of high-temperature superconducting bulk materials.

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Keiichi Tanabe, Director, Division of Electronic Devices, SRL, reported results of the project for development of superconducting network devices of a low power consumption type. The results included verification of 120GHz clock operation by an SFQ 8-bit shift register using an advanced process for nine Nb9 layers in LSI process development for low temperature device development and perfection of a design automation tool for logic synthesis in the development of basic circuit design technology. In the development of high-temperature devices, recent results and future challenges were reported including validation of high-speed operation by development of a new SFQ circuit layout (SBL method).

Titled "Application of Scanning Laser SQUID Microscope to LSI Inspection and Failure Analysis," Kiyoshi Nikawa, NEC Electronics Corporation, reported usefulness of a new scanning laser SQUID microscope including success in identifying (inspecting) acceptable and non-acceptable chips from entire 256-DRAM wafers and identification of open circuits (failure analysis) in entire chips.

Yuh Shiohara, Director, Division of Superconducting Tapes and Wires, SRL, reported the recent status of high critical current density and long-wire process technology development as targets of the applied and basic project. Activities in advanced R&D of application to equipment aimed at refining wires were also reported.

Titled "Activities in Development of Transformer Using Bi and Y Wires," Hidemi Hayashi, Kyushu Electric Power Co., Inc., reported a large critical current of Y wires in a magnetic field, low AC losses and development of element technologies of the transformer toward more practical development at low cost.

Titled "High-temperature Superconducting Magnets in Test Run on Yamanashi Linear Motor Train Experiment Line," Motohiro Igarashi, Central Japan Railway Company, reported that application of high-temperature superconducting magnets based on basic technology for commercialization of superconducting linear-motor trains established incorporating low-temperature superconducting magnets developed in the past will enable conductor cooling without using a refrigerant. Igarashi reported that this would simplify the construction and will enhance reliability of the linear-motor train system and that the recent test run verified that high-temperature superconducting magnets could be used in future linear-motor train systems.

Shigeo Nagaya, Chubu Electric Power Co., Inc. reported the development activities in Phase II of the SMES Project of NEDO and on the current status and future challenges for real system interconnection tests to verify achievement of both economy and performance of the SMES system technology based on the results obtained in the past development activities.

As a summary lecture, Osami Tsukamoto, Professor, Yokohama National University, delivered a keynote lecture titled "Superconductivity Technology Contributing to Social Activities - Superconductivity Technology Strategy Map." Tsukamoto reported that recent results of the superconductivity technology showed that commercialization was feasible and that a medium and long range direction could be visualized by drawing up an introductory scenario, technology map and technology roadmap having participated in the work to map out a superconductivity technology strategy map sponsored by the Ministry of Economy, Trade and Industry and NEDO. Tsukamoto emphasized that the personnel concerned should be confident about the future of superconductivity.

The meeting reaffirmed the significance and importance of further activities by the industry, academia and government for commercialization by moving in the direction shown in the superconductivity technology strategy map after having taken the first step toward commercialization based on the steady results achieved in R&D in various superconductivity segments.

Lecture scene

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

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Feature Articles:
Trends of Superconductivity Diagnostic and Medical Technologies
- Trends of High-Magnetic Field MRI Diagnostic System Technology -

Susumu Furuya
Chief Manager
Medical Community Relations Corporate Strategy Division
Hitachi Medical Corp.

Medium magnetic field superconducting systems ranging from 0.5 to 1.0T, which were the principal models in the MRI market of Japan, are being replaced by permanent magnet systems and the market has been divided into two parts: these medium systems and high magnetic field systems higher than 1.5T (See Fig. 1). In the future, 3.0T MRI systems for the whole body that have been approved under the Pharmaceutical Affairs Law are expected to spread.

For high magnetic field MRI systems (Fig. 2), high function and high speed image pickup technologies have been developed featuring a stable, high and uniform magnetic field and high S/N ratio by using superconducting magnets and a reinforced gradient magnetic field power system. For high function image pickup, research is underway on the imaging technology for the nerve system utilizing a high image resolution and on so-called "molecular imaging" for bio function imaging aside from conventional form images. In high-speed image pickup, the parallel imaging technology is spreading to shorten the image pickup time using multiple receive coils that have different sensitivity distributions. High speed acquisition of 3D data of moving organs such as the heart is also becoming feasible.

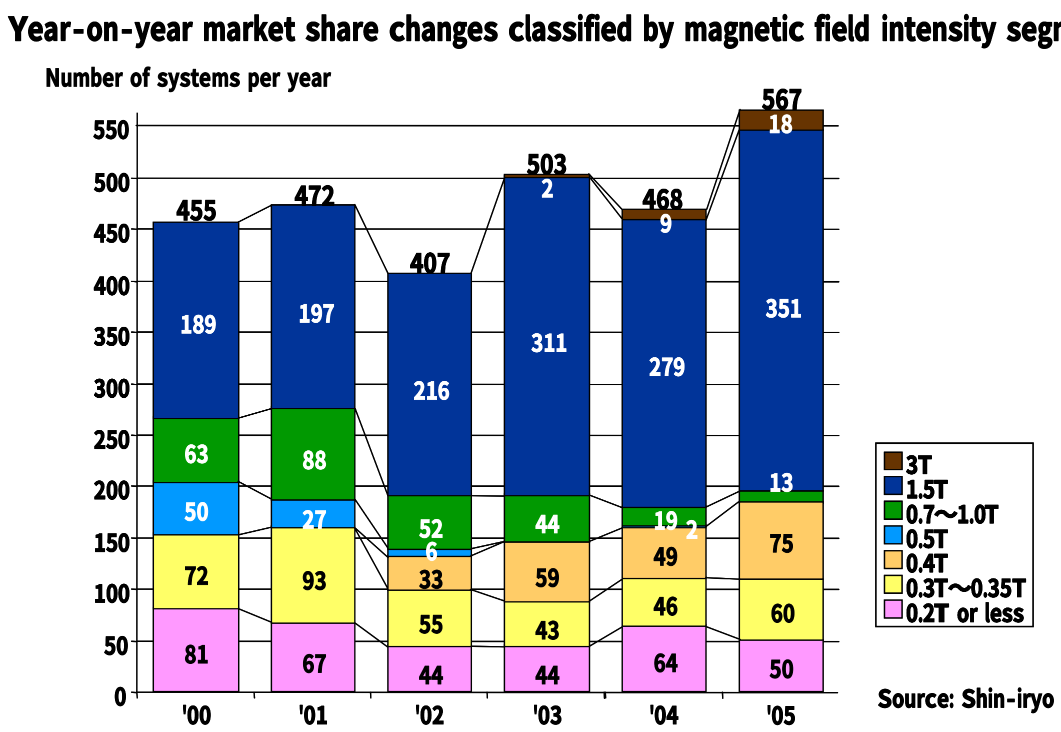

Fig. 1 Shares of MRI systems in market in Japan by magnetic field intensity

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In MRI systems, a high magnetic field intensity increases the intensity of received MR signals and enhances the S/N ratio of images. This will be advantageous in picking up high definition and high speed images. However, more caution is needed in operating super high magnetic field systems such as 3.0T systems in terms of safety. The RF irradiation power used in signal excitation in particular increases proportionally to the square of the magnetic field intensity and thus fast image picking up utilizing a high magnetic field intensity is becoming difficult within safety standards. Therefore, the parallel imaging technology mentioned above and the technology to control optimized irradiation waveforms are being developed. R&D of superconducting magnets of 7T and 11T for whole body systems is also being undertaken.

The tunnel type gantries are common for high magnetic field MRI systems because of the shape of superconducting magnets. However, open-type MRI systems placing superconducting magnets vertically in upper and lower positions are also manufactured in consideration of subjects (Fig. 3). MRI systems are expected to become diverse in the future through technology development of superconducting magnets such as high magnetic field systems, open systems and compact systems. Also the magnets made in Japan are expected to reentry into the market. The technology will be applied to medical treatment in the future such as drug delivery systems (DDS's) using bulk magnets.

Fig. 2 Example of 1.5T superconducting MRI system

Fig. 3 Open-type superconducting MRI system

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Feature Articles:
Trends of Superconductivity Diagnostic and Medical Technologies
- Current Status of SQUID Immune Test Technology -

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Graduate School of Information Science and Electrical Engineering
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Immune tests detect protein caused by various diseases using the coupling reaction of an antigen and antibody and are frequently used in medical diagnoses such as blood tests. In recent years, the importance of detecting various types of protein at a high speed and in high sensitivity is increasing and the R&D of various high performance test systems is being undertaken. One such activity is SQUID (Superconducting QUantum Interference Device) immune test technology using magnetic markers and SQUID magnetic sensors. In this test method, a test reagent (magnetic marker antibody) marked by magnetic nanoparticles is coupled to the protein to be detected and the amount of protein is measured based on a magnetic signal emitted by the magnetic marker. This test method assures a super high sensitivity that cannot be expected from the conventional optical technique and eliminates the so-called "washing" process, thereby affording fast tests. This method will allow fast detection of a very small quantity of protein with high sensitivity.

For these reasons, R&D of SQUID immune test technology has been undertaken in various countries and systematization research is conducted in Japan (Kyushu University, Toyohashi University of Technology, Advanced Research Laboratory, Hitachi Ltd. and others), the U. S. A. (UC Berkeley, Los Alamos National Laboratory, Texas Center for Superconductivity, Magnesensor Inc. and others), Europe (PTB Berlin, Julich Laboratory, Braunschweig University, Chalmers University and others) and Taiwan (Taiwan National University). In system development, the aim is to make a test piece at room temperature and SQUID cooled to a low temperature approach as near as possible (about 1mm). This is because the magnetic signal from the magnetic marker rapidly attenuates over the distance. A system of the SQUID microscope type has been developed for this purpose.

Tests and experiments of various types of protein (IL6, IL8, IgE and others) using the SQUID test technology are also being carried out. A detection sensitivity more than ten times compared with before is exhibited, enabling detection of a trace amount on an atomic/molecular level. High-speed tests in the liquid phase eliminating the "washing" process are also being conducted. Usefulness compared with the conventional optical technique is being demonstrated. Nevertheless, the development of a magnetic marker that shows a high dispersiveness without causing coagulation or sedimentation in a solution and that emits a large magnetic signal that is optimum to this technique is an important objective in addition to high performance of systems to succeed in commercialization. Successful development of these elements will ensure further enhancement in the SQUID test technology.

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Feature Articles:
Trends of Superconductivity Diagnostic and Medical Technologies
- Global Trends of Magnetocardiograph -

Akihiko Kandori
Advanced Research Laboratory
Hitachi Ltd.

The magnetocardiograph features a very high sensitivity in detecting ischemia and is useful for detecting abnormal electrical excitation. For these reasons, the magnetocardiograph is attracting attention as entirely new medical equipment. [1)] The magnetocardiograph has started to be used by medical organizations in Japan, the U. S. A., Germany, Finland, Italy, Taiwan, China, Korea and others for research purposes. The number of papers on magnetocardiograms is increasing rapidly. Year after year, twice as many papers are published compared to the previous year. Papers on magnetocardiograms are appearing in journals such as Circulation [2)] and PACE [3)] that are well known as magazines specializing in heart diseases.

Against this backdrop, a satellite symposium "Global trends of magnetocardiograph" was held on July 8, 2006, at the 23rd Annual Meeting of the Japanese Society of Electrocardiology as the first step toward standardization of magnetocardiograms. Presentations on the effectiveness of magnetocardiograms were made by Dr. Kirsten Tolstrup, Cedars-Sinai Medical Center, the U. S. A., Dr. Chau-Chung Wu, National Taiwan University Hospital, Taiwan, Prof. Boyoung Joung, Yonsei University College of Medicine, Korea, Prof. Shigeyuki Watanabe, University of Tsukuba, Japan, and Prof. Satsuki Yamada, University of Tsukuba (currently at Mayo Clinic) and other purposes. The presentation made by Dr. Tolstrup in particular was very interesting. Comparing scintigraphy under exercised test (3-hour examination using radioisotope) and magnetocardiogram during a rest (examination for about 10 minutes), Dr. Tolstrup reported that the sensitivities of ischemia detection ratios of the two were almost equal. Dr. Tolstrup commented that magnetocardiographs were best suited for screening examinations of patients with chest pains and that scintigraphy which is hazardous would be replaced by magnetocardiographs. The presentations made by the other presenters also reported that magnetocardiograms had a high ischemia detection ratio. Lastly, the symposium agreed to cooperate in undertaking activities to standardize magnetocardiograms.

In Japan, a textbook on magnetocardiograms "Magnetocardiogram interpretation : A basic manual," authored and edited by Prof. Keiji Tsukada, Okayama University Graduate School, under the supervision of Prof. Iwao Yamaguchi, director of Tsukuba University Hospital and councilor of University of Tsukuba, in August by Corona Publishing Co., Ltd. [4)] There are moves in Europe also toward the standardization of magnetocardiograms. A workshop titled "European Taskforce of MCG" is scheduled at BIOMAC '2006 in Vancouver, Canada, in August. Worldwide cooperation in standardization of magnetocardiographs will be undertaken in the future and magnetocardiographs will be used as a more effective tool in clinical examinations.

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Feature Articles:
Trends of Superconductivity Diagnostic and Medical Technologies
- View of MT-DDS (Magnetic Target Drug Delivery System) Technology -

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Division of Sustainable Energy and Environmental Engineering
Graduate School of Engineering
Osaka University

Almost all medicines have side effects other than the originally intended efficacies. Side effects are caused when medicines are used in excess of optimum concentrations, distributed in parts other than those intended or are used at a time when it is not necessary. In other words, the degree of side effects can be mitigated significantly by controlling medicine distribution inside the body quantitatively, spatially and timewise. Studies for optimization of medicine dosage examine the drug delivery system (DDS), which is considered in advanced medicine a key technology.

In DDS, endowing a character to a medicine to direct to a target is called "targeting." A substance that has an affinity with the target is used as a carrier and a drug as an object is delivered using the in vivo behavior of the carrier. Methodologies to accomplish targeting include: (1) Local dose, (2) selective activation in a target area, (3) use of a medicine carrier and (4) control of in vivo behaviors from the outside. As a technology to drastically enhance the targeting efficiency, "magnetic target DDS (MT-DDS), which is one type of (4), has been attracting worldwide attention.

In MT-DDS, ferromagnetic (nano) particles are attached onto the drug and a magnetic field is impressed to ferromagnetic particles to generate a magnetic force, by which a drug is guided. The drug is introduced into the body by intravenous injection and is guided by placing a magnet outside the body. The following three modes are considered for the MT-DDS system in practical use. 1) A system to prevent dispersion of a drug by a magnetic force. 2) A system to trap and accumulate a drug in some part of a blood vessel. 3) A system to guide a drug in a desired direction to deliver it to an intended diseased part. A development goal will be to implement System 3) in a deep part of the body when application to cancer treatment is considered.

This concept has been proposed in the past, but development of technology to translate it into reality has not been successful. One reason for this is that in human bodies, a drug cannot be made sufficiently voluminous so as to require a magnetic force. A large magnetic field and magnetic gradient cannot be formed several centimeters away from the magnet and there are requests that drug size should be limited to about 200nm or less to avoid phagocytosis. These limits reduce the level of magnetic force. These problems can be solved by generating a strong magnetic field and magnetic gradient in a deep part of the body. The goal will be to create a 5T/m magnetic field at 0.5T several centimeters inside the body. Calculations and experiments have shown that this goal can be accomplished using a superconducting magnet. Animal experiments have already been conducted and a consortium of the Medical, Pharmaceutical and Engineering Departments and manufacturers of medical equipment is actively undertaking R&D. This technology is expected to become key technology in advanced medicine in the near future.

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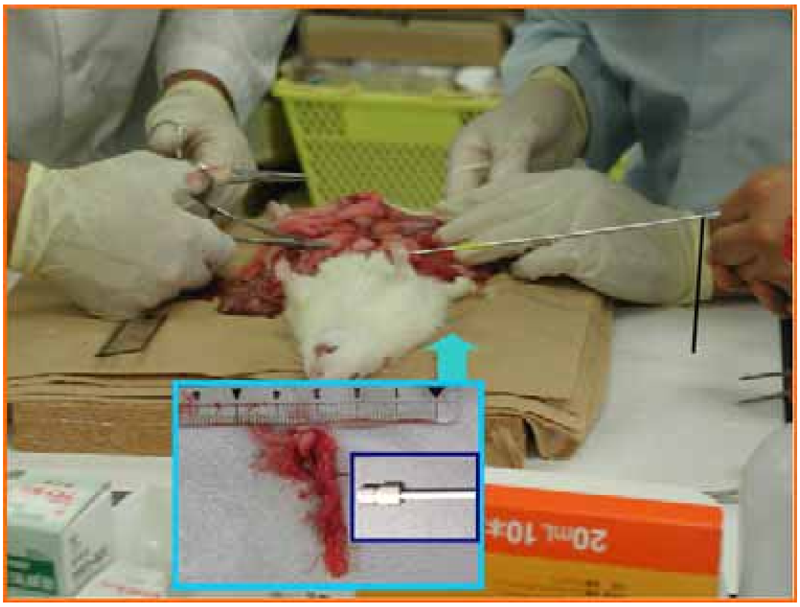

Particle residence experiment with a rat applying a magnetic field. Ferromagnetic particles are introduced into blood vessel of the rat and controllability of particles by the magnetic field has been verified.

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Feature Articles:
Trends of Superconductivity Diagnostic and Medical Technologies - View of Technology for Miniaturization of Charged Particle Therapy Equipment -

Satoru Yamada
Promotion of Carbon Therapy Section
Research Center for Charged Particle Therapy
National Institute of Radiological Sciences

Radiating protons, carbon and other ions into a substance, ions stop at a certain depth that is determined by ion energy. Large amount of the kinetic energy is transferred to the atoms of the substance in a narrow region immediately before the end points. This character of heavy charged particles produces excellent results in heavy ion therapy.

The dose localization of heavy particle beams is far superior to X-rays and gamma-rays that have been used in conventional radiation therapy, suggesting possibilities for therapy with fewer side effects. However, ions have to be accelerated to near the light velocity to use ions in deeply seated cancer treatment, requiring a large accelerator such as a cyclotron and synchrotron. These large accelerators cannot be housed in ordinary hospitals and special buildings to house them are needed. For example, a facility at the National Institute of Radiological Sciences can deliver silicone ions 30cm inside human bodies. This facility requires a building of 65 x 120 m^2, or the area of a soccer ground, to house it. As a result of development research carried out by the Institute to make equipment more compact aimed at spreading carbon beam therapy, the equipment for carbon beam therapy can be reduced to a size housed in a building of about 50 x 60 m^2. without any reduction in beam properties. Compared with carbon, protons are far lighter and can be accelerated easily. Nevertheless, the equipment at the National Cancer Center of Japan requires a building of about 40 x 60m^2.

Miniaturization of accelerators using the superconducting technology has been studied. Recently, two superconducting proton systems have been completed in Europe and test runs have been commenced for the start of therapy. As far as the accelerator size is concerned, for example, a proton synchrotron about 20m in circumference (average diameter 6.4m) can be made compact, to a cyclotron of about 4m in outside diameter. One drawback with the superconducting cyclotron is that outgoing energy is fixed. For treatment of cancers, whose depths vary from one patient to another, proton energy is reduced by passing it through a carbon plate or other material. This process results in a wide spread in energy and protons with energy widths below a predetermined value must be selected with an analizer magnet. This greatly reduces the proton intensity and generates unwanted activation. Furthermore, a beam transport system, beam shaping equipment and other equipment occupy a far larger space than the accelerator itself and the medical side is making a variety of requests including rapid switching of the magnetic field (about 1 minute) for this part. Application of superconductivity to heavy ion therapy is yet to start.

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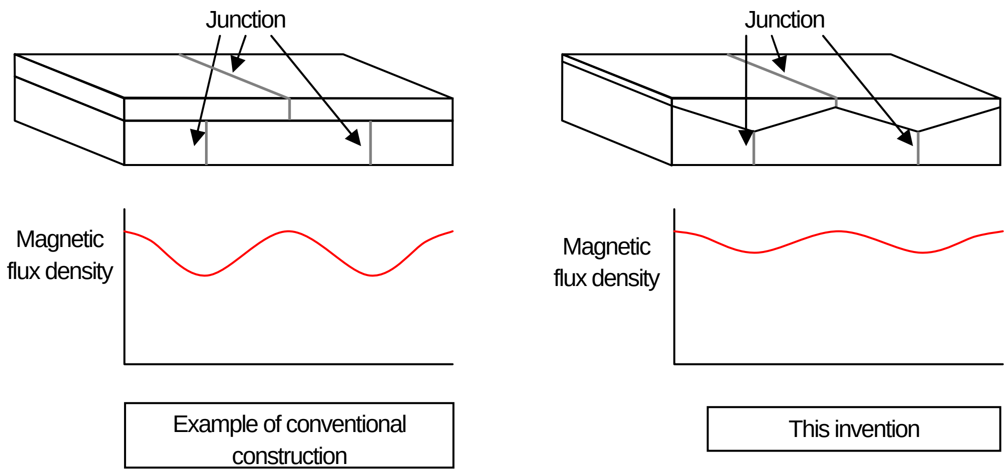
Patent Information

Introduction of Published Unexamined Patents in the 1st Quarter of Fiscal 2006

The following are ISTEC's patents published from April through June, 2006. For more information, access the homepage of the Patent Office of Japan and visit the Industrial Property Digital Library (IPDL).

1) Publication No. 2006-101585 "Superconducting Bearing and Magnetic Levitation System"

This invention relates to superconducting members in a magnetic bearing and a superconducting transfer vehicle, in which the pinning forces of the superconductors are utilized for levitation by facing the superconducting members to permanent magnetic members. Such superconducting members join plural superconductors to obtain a large area of the facing surface. However, the trapped magnetic field decreases near the junctions, causing a non- uniformity of the magnetic field and becoming a major factor for generation of electric losses. This invention is applied a construction that stacks the superconductor layers that join plural superconductors, and characterized that the superconductors of each layer are formed in a chevron form and junctions of superconductors of one layer are located in apexes of chevrons of other layer. The superconducting members of this invention excel in trapped magnetic field characteristics.



2) Publication No. 2006-117986 "Measuring and Evaluation Method for a Plume, Laser Ablation Method and Laser Ablation System"

This invention relates to plume measuring and evaluation methods, laser ablation method and laser ablation system. The purpose of this invention is to deposit a laser ablation thin film that has a good crystalline property or stable electric characteristics with a good reproducibility. One of the causes for non-uniform or unstable thin film characteristics in the laser ablation method is instability of laser oscillation. This invention is featured by acquirement of light intensity data of plume, generated when a laser beam is radiated onto the evaporation source target, using an area image sensor and estimation of the plume shape in real time using the foregoing measurement results. This enables control of laser oscillation intensity according to the change of the plume shape. A plume with a stable shape can be maintained for a long time. This invention is especially effective in the film deposition process of high-temperature oxide superconducting devices that require high quality thin films.

(Katsuo Nakazato, Director, Research and Development Promotion Division, SRL/ISTEC)

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Standardization Activities

Topics in June

- IEC-APC Honors Professor Shintomi and Murase and Other Persons for Contribution to IEC International Standardization -

At its General Assembly of 16th IEC Activity Promotion Committee held on Wednesday, May 10, 2006, the IEC Activity Promotion Committee (IEC-APC) honored Prof. Takakazu Shintomi of Nihon University, Prof. Satoru Murase of Okayama University and 11 other persons for a major contribution made to IEC international standardization by conferring IEC-APC chairperson awards.

The IEC-APC chairperson awards are awarded each year to individuals or groups making a prominent contribution in the IEC segment such as development of IEC standards proposed by Japan. The awards are presented by IEC-APC that was inaugurated in 1991 for contribution to IEC (International Electrotechnical Commission) and for reflection of the views of the industry.

In 2006, one person received the special award, 11 persons received chairperson awards, and eight persons received letters of appreciation.

The IEC-APC chairperson award was awarded to Prof. Takakazu Shintomi of Nihon University (Graduate School) for his great contribution to standardization in Japan and in the world for IEC-APC through his activities at WG6 of IEC/TC90 (Superconductivity) since 1995 in promoting international standardization of IEC/TC90 and for his service as a WG6 convener.

The IEC-APC chairperson award was awarded to Prof. Satoru Murase of the National University Corporation, Okayama University (Graduate School) for his great contribution to standardization in Japan and in the world for promotion of superconductivity standardization since 1990 when Japan accepted the role as an international secretariat and for his service as a WG11 convener.

Commemorative photograph of award recipients (Prof. Satoru Murase on right of back row)

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Topics in August

- NEDO Awards Research Contract for "Standardization of Technical Infrastructure for Superconducting Power Devices and Systems" to ISTEC -

On May 11, 2006, the Independent Administrative Agency, New Energy and Industrial Technology Development Organization (NEDO) awarded a research contract to the International Superconductivity Technology Center (ISTEC), a foundation on standardization of technical infrastructure for superconducting power devices and systems.

The contract is outlined in the following.

Purposes

As part of the standardization of technical infrastructure for superconducting power devices and systems, the contract calls for a study of technologies related to product standardization of superconducting magnetic energy storage systems (SMES, flywheels), superconducting power cables, superconducting current limiters, superconducting transformers and other equipment for use in mapping out and developing draft international standards documents. Studies under this project shall be undertaken in conjunction with: (1) Ongoing project "Superconducting Power Network Control Technology Development" undertaken between 2004 and 2007 and (2) Ongoing project "Research and Development of Superconductivity Applied Basic Technology" undertaken between 2003 and 2007.

Study Themes

Studies shall be undertaken on the following themes.

(1) Study of current lead characteristics

To reflect the results of technical studies of characteristic test methods of current leads that are essential to superconducting power devices such as superconducting power cables, superconducting current limiters, superconducting transformers, SMES and superconducting rotating machines on draft standards. To develop new work item proposals (NWIPs) targeting at completion in 2006 for contribution to IEC international standardization.

(2) Study of characteristics of long wires

To study test technologies and test methods centering on a critical current (Ic) test method and mechanical characteristic test methods for long Nb-Ti, Nb_3Sn and other low-temperature superconducting wires and long-Bi, Y and other high-temperature superconducting wires. To develop draft standards based on them and to seek an international consensus aimed at proposing them as international standards at meetings with international experts.

(3) Study of technologies for SMES and other superconducting power devices

To determine objects for standardization of superconducting power devices based on results of studies in the study contract on technical infrastructure of superconducting power devices gained up to March 2006 including superconducting power cables, superconducting current limiters, superconducting transformers, SMES and superconducting rotating machines.

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Study Period

April 2006 to March 2009

Study Organization

To be studied by Technical Study Committee chaired by Prof. Kozo Osamura (Research Institute for Applied Sciences), by SMES Subcommittee chaired by Prof. Takakazu Shintomi (Nihon University), by Current Lead Subcommittee chaired by Prof. Takakazu Shintomi, and by Long Wire Characteristic Subcommittee chaired by Dr. Koichi Nakao (ISTEC/SRL).

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(Yasuzo Tanaka, Director, Standardization Department, ISTEC)

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