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What's New in the World of Superconductivity (June, 2013)

초전도 뉴스 –세계의 동향-

超导新闻 -世界的动向-

chāo dǎo xīnwén - shìjiè de dòngxiàng-

Yutaka Yamada, Principal Research Fellow
Superconductivity Research Laboratory, ISTEC

★News sources and related areas in this issue

▶ Wire 선 재료 线材料 [xiàn cáiliào]

The New York State Superconductor Tech. Summit from Wire to MRI

SuperPower (June 3, 2013)

The Third New York State Superconductor Technology Summit was held on May 7 at the College of Nanoscale Science and Engineering (CNSE) in Albany, New York. The summit was underwritten by the New York State Energy Research and Development Authority (NYSERDA) and was organized and co-sponsored by MTECH Laboratories, GE Global Research, Hypres Inc., Philips Healthcare, and SuperPower Inc. The summit stressed the highly successful superconducting MRI businesses of both GE

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and Philips as well as newer superconductivity applications for improving the electrical grid. Francis J. Murray Jr., President and CEO of NYSERDA, commented, "As we continue to improve the state's power transmission system, superconductor technology presents innovative and exciting opportunities to provide the power needed to make the grid smarter, more resilient and more flexible to meet growing energy demands… NYSERDA is proud of our tradition of partnership with companies here in New York that are working on groundbreaking research and applications for superconductivity."
Three important cable HTS cable demonstrations have taken or are taking place in New York state: the Albany HTS Cable Project (managed by SuperPower and involving the world's first installation of a superconducting cable in a live grid from 2006 to 2009), the Long Island Power Authority (LIPA) cable (currently under construction), and the Project Hydra Cable (about to be installed in the Consolidated Edison grid in New York City). NYSERDA has supported each of these projects in an effort to demonstrate the energy efficiency benefits of superconducting cables.
Dr. Michael J. Hennessy, President and Co-Founder of MTECH Laboratories summarized a recurring theme of the summit by stating that "New York State is home to the full range of businesses that support superconductivity applications, from the superconducting wire supplier, SuperPower, to the device and system developers such as GE and Philips, to the refrigeration providers such as CryoMech and Q-Drive, and the schools and STEM programs, including Tech Valley High School, SCCC, CNSE, Union College and Union Graduate College, that inspire, train and develop our workforce. This is a force that is second to none."
Other developmental programs that were presented at the summit included the development of a superconducting magnetic energy storage system (SMES) by SuperPower and Brookhaven National Laboratory in collaboration with ABB Inc. and the University of Houston and two programs to develop alternatives to the use of rare earth elements for wind turbine generators: one involving SuperPower and the other being led by the Brookhaven National Laboratory. Recent developments in quantum computing and information processing, medical technology, and energy storage were also discussed. A short video entitled, "Superconductivity…from New York State to the World" was featured at the summit and can be viewed at http://youtu.be/uQRgAYzkU1s.

Source: "New York's Superconductivity Industry Highlights Technology and Economic Benefits"
SuperPower Inc. press release (June 3, 213)
URL:
http://www.superpower-inc.com/content/new-york's-superconductivity-industry-highlights-technology-and-economic-benefits
Contact: Traute F. Lehner, tlehner@superpower-inc.com

Financial Report and Growing Order Backlog of 2G Wire Superconductor Technologies Inc. (May 8, 2013)

Superconductor Technologies Inc. (STI) has reported its fiscal results for the first fiscal quarter ending March 30, 2013. The net revenues for the first quarter were US $776,000, compared with $399,000 for the same period in the previous fiscal year. The net loss totaled $2.4 million, compared with $3.0 million for the same period in the previous fiscal year. As of March 30, 2013, STI had $1.7 million in cash and cash

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equivalents. STI has since received $1.95 million in net proceeds from a registered direct offering of common stock and warrants.
Jeff Quiram, STI's president and chief executive officer, commented, "We are executing our strategy to commercialize Conductus® wire by establishing a diversified customer base with a variety of superconducting needs. STI entered 2013 positioned to begin pilot production. On April 23rd, we announced receipt of purchase orders from several strategic customers that are qualifying Conductus wire in specific product designs. Since that announcement, our order backlog has continued to grow… Looking ahead, our current orders and other commitments will consume all of the wire we can produce at least until the third quarter of 2013." STI will prioritize shipments of Conductus® wire to customers requiring the wire to complete product evaluations. Most of the pending customer orders are for wire with a critical current of 250-400 A/cm-w. Additionally, efforts are being focused on the production of wire lengths with a critical current of 500 A/cm-w for a cable demonstration project.

Source: "Superconductor Technologies Reports First Quarter 2013 Results"
Superconductor Technologies Inc. press release (May 8, 2013)
URL: http://phx.corporate-ir.net/staging/phoenix.zhtml?c=70847&p=irol-newsArticle&ID=1816855&highlight
Contact: Investor Relations, Cathy Mattison or Becky Herrick of LHA for Superconductor Technologies Inc., invest@suptech.com, ; HTS Wire, Mike Beaumont of STI, mbeaumont@suptech.com

▶Electronics 엘렉트로닉스 电子应用 [diànzǐyè yìngyòng]

NASA, Google, USRA Selected "D-Wave Two™" Quantum Computer for the New Artificial Intelligence Lab., to be Operational Soon

D-Wave Systems Inc. (May 16, 2013)

D-Wave Systems Inc. has announced that its new 512-qubit quantum computer, the D-Wave Two™, will be installed at the new Quantum Artificial Intelligence Lab, a collaboration among NASA, Google, and the Universities Space Research Association (USRA). The quantum computer will be used to advance machine learning to enable to solution of challenging computer science problems. Installation of the system has already begun, and the quantum computer is expected to become available to researchers during the third fiscal quarter of this year. As part of the selection process, Google, NASA, and USRA created a series of benchmark and acceptance tests that the D-Wave 512-qubit system was required to pass. The D-Wave Two system successfully met, and in some cases exceeded by a large margin, all the required performance specifications.
The D-Wave system will be used to develop applications for a broad range of complex problems including machine learning, web searches, speech recognition, planning and scheduling, the search for exoplanets, and the support of operations at mission control centers. The system will be available to the broader U.S. academic community via USRA.

Source: "D-Wave Two™ Quantum Computer Selected for New Quantum Artificial Intelligence Initiative,

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System to be Installed at NASA's Ames Research Center, and Operational in Q3"
D-Wave Systems Inc. press release (May 16, 2013)
URL: http://www.dwavesys.com/en/pressreleases.html
Contact: Janice Odell, jan@fordodell.com

▸Accelerator 가속기 加速器 [jiāsùqì]

Received Contract for 120 RF Cavities

RI Research Instruments GmbH (May 7, 2013)

RI Research Instruments GmbH, a majority-owned subsidiary of Bruker Energy & Supercon Technologies, Inc. (BEST), has been awarded an option for an additional 120 superconducting radiofrequency (rf) cavities valued at approximately $7.3 million. The option is in addition to an ongoing contract (valued at 24.9 million Euros) for 300 cavities intended for the European XFEL, a new international research facility located near Hamburg, Germany. The qualification phase for the RI infrastructure was recently completed successfully, and the shipment of series cavities under the original contract is expected to begin during the second quarter of 2013. Deutsches Elektronen-Synchrotron (DESY) is the majority shareholder in the European XFEL and is in charge of building and operating the accelerator facility.

Source: "RI Research Instruments GmbH Received DESY Contract for 120 RF Cavities"
RI Research Instruments GmbH press release (May 7, 2013)
URL:http://www.research-instruments.de
Contact: Hanspeter Vogel, Hanspeter.Vogel@research-instruments.de

▸Basics 기초 基础[jīchǔ]

Magnetism/Superconductivity Coexist in Iron-based Superconductors?

Ames Laboratory (June 5, 2013)

Researchers at the U.S. Department of Energy's Ames Laboratory have reported unexpected changes in electrical resistivity in iron-based superconductors that support a close relation between magnetism and superconductivity in these materials. The group observed that in barium-iron-arsenide compounds with different chemical substitutions, the directions of the smallest and largest resistivity within the conducting layers were significantly dependent on the composition of the compounds and, in some compounds, changed. These changes could only be explained by a close connection between the underlying magnetic

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behavior and the phenomenon of superconductivity. In conventional superconductors, magnetism and superconductivity do not coexist, with one suppressing the other. In iron-based superconductors, however, a significant overlap between magnetism and superconductivity is sometimes seen. While unique measurements of the materials' properties can thus be made in this region of magnetism/superconductivity coexistence, such measurements are complicated by a split in the crystal's structural domains (or structural twins), which makes studying directional electronic properties difficult. The Ames researchers have eliminated these structural domains by developing a technique in which single crystals are physically pulled apart by suspending a sample using wires in a horseshoe-shaped bracket that can be mechanically stretched. The assembly is placed in a liquid helium cryostat and cooled to the required temperature. Polarized optical microscopy is then used to distinguish the different structural domains and to verify that the samples are in a detwinned state. The electric resistivity can then be measured. The group's work has been reported in *Nature Communications*.

Source: "Resistivity switch is window to role of magnetism in iron-based superconductors"
Ames Laboratory press release (June 5, 2013)
URL: https://www.ameslab.gov/node/7748
Contact: Ruslan Prozorov, prozorov@ameslab.gov
Breehan Gerleman Lucchesi, breehan@ameslab.gov

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Feature Article: Refrigeration and Cryogenic Technologies - Advancement of Brayton Refrigerator thus far

Norihisa Nara
Cryogenic Development Project, Tsukuba Laboratories
Development and Engineering Division
Taiyo Nippon Sanso Corporation

The research and development into high temperature superconducting (HTS) power equipment anticipated as vital energy saving power technology, has entered the phase aimed at practical applications. Amidst this, the needs of refrigeration systems for HTS power equipment have increased. The required specifications include 1) operating temperatures and cooling capacities to sustain superconductivity, 2) long-term continuous operational reliability, 3) operating cooling efficiencies (low running costs), 4) system compactness (compact footprint), and 5) low maintenance costs.

Currently, the operating temperatures of refrigeration systems employed for cooling HTS power equipment range from 40 to 80K, with cooling capacities ranging from 2 to 10kW at 65 K operation. Compact cryocoolers currently available in the market provide cooling capacities of around 1kW at 80K, and with rubbing parts require regular maintenance once per year. On the other hand, large-scale cryogenic systems such as cryogenic air separation units and helium liquefiers have employed expansion turbines, which have been proven its large cooling capacities and durability. However, the cooling capacities of such systems far exceed that required by HTS power equipment, and to address this, in 2011, a prototype neon turbo-Brayton cycle refrigerator was fabricated using neon as the working fluid.

The prototype refrigerator consists mainly of a turbo compressor, a main heat exchanger, an expansion turbine, a sub-cool heat exchanger, and a liquid nitrogen circulation pump. Figure 1 shows the simple schematic of the cooling system flow combining a refrigerator and superconducting power equipment. The superconducting power equipment is cooled using sub-cooled liquid nitrogen, cooled to around 66K through the sub-cool heat exchanger. Furthermore, the adoption of magnetic bearings in the compressor and in the expansion turbine eliminates any rub between moving parts, thereby resulting in a maintenance-free refrigerator. Figure 2 shows the cooling test run of a HTS transformer system combined with 2MVA superconducting transformer and cooling system. The main heat exchanger is housed in a centrally located cold box, and the expansion turbine is also installed in the cold box. The turbo compressor used to compress neon is located next to the cold box. The automatic control of the turbo-compressor's rotational speed, which

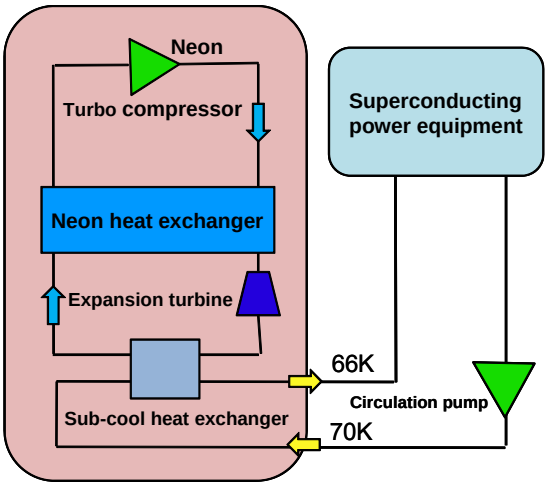

Fig. 1 Cooling system flow designed for superconducting power equipment

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correspond to heat load changes of the superconducting transformer, worked well, and liquid nitrogen temperature inside the superconducting transformer was stable within ±1K. Refrigerator efficiency at partial load operation is improved by this technology.

The transformer-cooling test required a large footprint because of the auxiliary equipment necessary for the test, as shown in Figure 2. By eliminating unnecessary auxiliary equipment for the commercial model and revaluating the equipment arrangement, it was possible to further reduce the footprint of the turbo refrigerator component, as shown in Figure 3. The compact turbo refrigerator component has a cooling capacity of 2kW@ 65K. Also, as shown in the picture, the packaged refrigerator can be easily transported and installed.

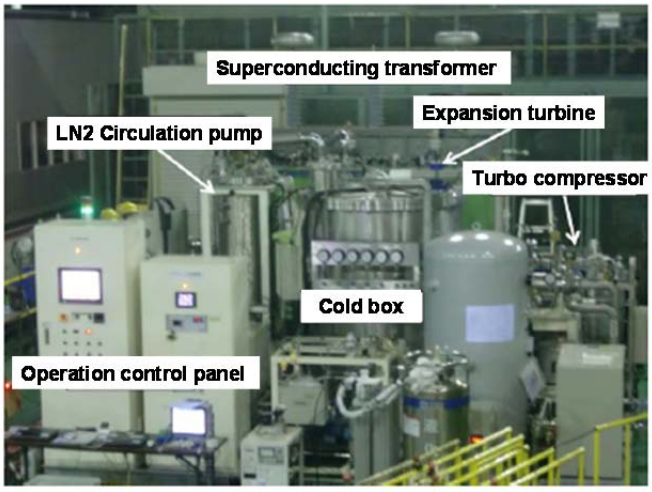

Fig. 2 Cooling test run of a HTS superconducting transformer

Fig. 3 2 kW turbo refrigerator component

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Feature Article: Refrigeration and Cryogenic Technologies - The Operational Status of the Cooling System for the High Temperature Superconducting Cable Demonstration Project

Naoko Nakamura
Vice Senior Research Fellow
Mayekawa MFG. Co., Ltd.

As part of the high temperature superconducting (HTS) cable demonstration project, HTS cables have been installed at the Asahi substation of Tokyo Electric Power Company, with investigations undertaken to characterize performance, practicality, reliability, and maintainability of HTS cables and cooling systems when connected to the grids. Three companies have undertaken the project, Tokyo Electric Power Company, Sumitomo Electric Industries, Ltd., and Mayekawa MFG. Co., Ltd., commissioned by the New Energy and Industrial Technology Development Organization (NEDO). Cooling system unit test and HTS cable connection tests undertaken prior to actual connection to power grids confirmed system reliability. Power grid connection was performed on 29th October 2012, and one year continuous operations launched. After connection to the power grid, the system has fundamentally functioned without human interaction, with day-to-day load changes and operational status of the cooling system remotely supervised in order to evaluate performance attributes such as cable heat loads, cooling capacities, etc. By the end of May 2013, around 210 days have passed since installation, and continuous trouble-free and stable operation was confirmed without the need for additional liquid nitrogen.

The cooling system is a Stirling cryocooler having a 1kW@77K cooling capacity, circulation pump, and reservoir tank. Sub-cool liquid nitrogen is employed as the coolant. Taking into consideration pressure loss and temperature control at the heat exchanger, two Stirling cryocooler units have been arranged in each column, with three columns operating in parallel. The circulation pumps have been arranged with two centrifugal units in parallel. One of the three columns of refrigerators and one unit from two circulation pumps are reserved. Considering the potential practicability of HTS cables, current Stirling cryocoolers do not provide sufficient capacity, efficiency and maintainability, and the need for further refrigerator development having greater capacities and enhanced performance is desired. Therefore, in parallel with demonstration trials undertaken since February 2011, this project has focused on the development of a Brayton-refrigerator, designed to aim for a cooling capability of 5 kW, COP 0.1.

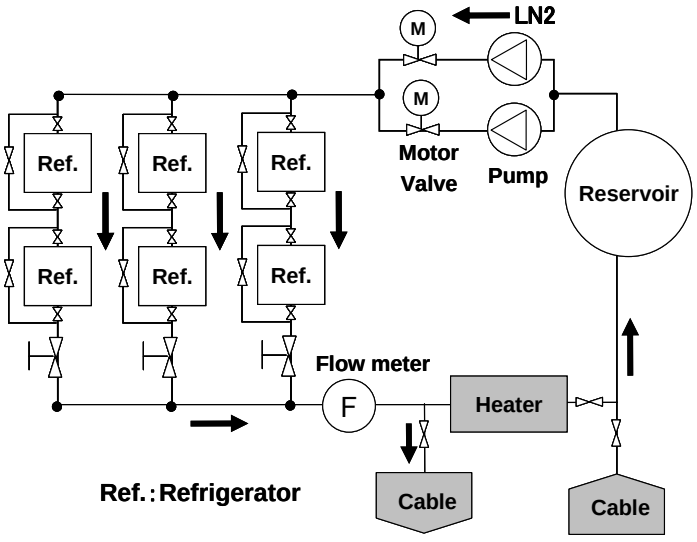

Fig. 1 System flow

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Since Stirling cryocoolers' maintenance intervals are 8000 hours, scheduled maintenance is required during the demonstration trials. This cooling system is equipped with a bypass line and an on-off valve in order to replace the refrigerator whilst maintaining cooling operations. Refrigerator maintenance for each unit commenced since April 2013. There were no significant changes in temperature, pressure, and volume flow of liquid nitrogen during or after the refrigerator replacement, thereby averting moisture from entering the liquid nitrogen system. Whilst refrigerator maintenance will be undertaken accordingly, future investigations are ongoing to characterize performance, practicality, reliability, and maintainability of HTS cable systems, with the acquisition of long-term operational data, including any observable changes between seasons (electric load, heat load).

Fig. 2 Cooling system

Finally, anyone interested in the everyday status of the HTS cable at the Asahi substation is directed to the following website.
http://www.sei.co.jp/super/cable/jissho.html

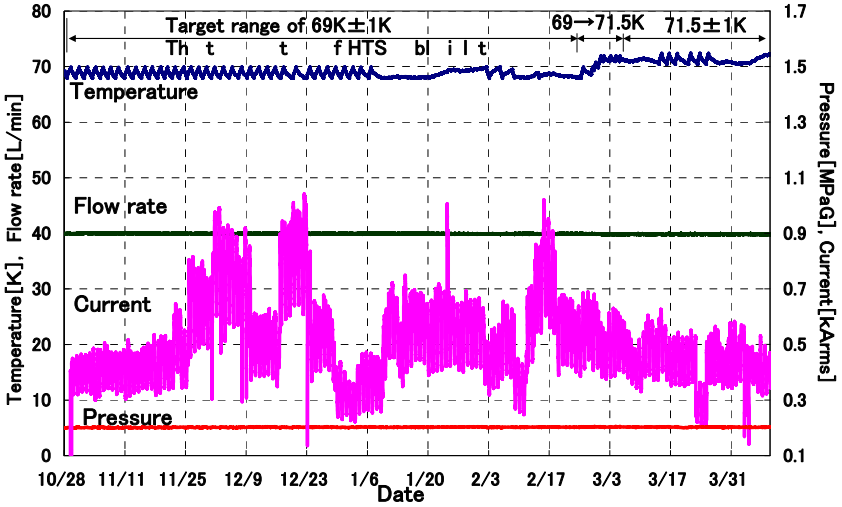

Fig. 3 Operational status of cable demonstration tests after connecting to power grids

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Feature Article: Refrigeration and Cryogenic Technologies - The Development of Low Thermal Conductivity Current Leads Utilizing Yttrium-based Oxide Superconducting Wires

Masahiro Minowa
Advanced Technology Development Section
R&D Center
SWCC Showa Cable Systems Co., Ltd.

Research and development aimed at practical equipment utilizin g superconducting wires in magnets, motors, cables and transformers for example, has been vigorously increasing in recent years. However, the cost of cryocooling superconducting equipment needs to be reduced furt her so that superconductor-based applications become economically viable. To address this issue, the development of refrigerators having greater efficiencies and low temperature vessels with superior adiabatic characteristics has been progressing. Additionally, reducing thermal conductivities from conductors electrically connecting the power supply, usually at room temperat ure, to components operating at cryogenic temperatures becomes more important when the current carrying capacity in creases. Current leads connecting power supply components to supercondu cting equipment function to supply power from a power supply (oper ating at room temperature), to sup erconducting equipment (at cr yogenic temperatures), as well as minimize the heat conductivity due to the large temperature gradients.

The current lead conducto r materials vary according to the installation environme nt. For example, oxide superconductors such as bismuth-based conductors can be employed where the installation environmental temperatures are lower than liquid nitrogen temperat ures. Additionally, oxide superconductors have much lower thermal conductivities compared to copper and t herefore minimal thermal conductivity due to heat conduction. Also, during operation, high currents can be transmitted wit hout Joule heating effects, thus exhibiting the ideal current lead c haracteristics necessary for super conducting equipment. However, these superconducting current le ads are not suitable for superconducting cable terminals cooled using liquid nitrogen, since the temperature of the areas connecting the current leads to e quipment increases. To circumvent this, investigatio ns to reduce thermal conductivi ties at the cable term inals involve e mploying Peltier current leads equipped with a Peltier element embedded within the conductors [1)].

Amongst the superconducting current le ads, those employing bismuth-based bulk superconductors are well known. These bismuth- based current leads are being employed in superconducting equipment such as magnets, however there are issues with bulk materials that in clude their susceptibility to d amage by excessive impacts and str esses. Furthermore, several bismuth-based current leads are req uired for large-scale superconducting equipment, and are depen dent upon the magnetic field environment of their installation. To address such issues, Yttrium-based superconducting current leads have been developed [2)] employing Yttrium-based superconducting tapes, which are less susceptible to impact damage and can be used even w hen they are not straight since the super conductor is deposited thinly onto a flexible metal substrate. Recent developments in this field have see n Yttrium-based superconducting wires with artificial pinning centers exhibiting large critical current values with modest changes in characteristics in a magnetic

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field [3]. It is therefore considered possible to design current leads exhibiting greater current carrying capacities and reduced thermal conductivities compared to conventional ones available today.

Yttrium-based tapes have been fabricated typically having around 5-10 mm width. The design by bundling and then connecting several tapes to an electrode establishes the current-carrying capacity of the current lead required. During this design stage, there are risks that if the electrical resistance of an individual tape differs at the tape and electrode interface, the associated drift will thwart the designed current-carrying capacities. This may prove to be a significant issue for current leads in particular that need large current capacity of more than several kA, and therefore, quantitative drift evaluations have been performed utilizing a Rogowski coil[4]. These evaluations are expected to produce a greater under standing regarding the influence that drift may cause to current carrying characteristics of current leads, and investigations into joining technology with reduced resistance fluctuations, all leading to the development of high capacity and high performance current leads.

Finally, our reference example in Table 1 shows the draft specification of a 1kA-current lead that utilizes Yttrium-based tapes in conductors. Figure 1 shows an outline of prototype current leads fabricated based upon the draft specifications: 30mins, 3.3 kA (@77 K, s.f.) continuous current application testing employing this prototype confirmed no increase in resistance and no quench occurrences [5]. Future plans are to design and develop further compact current leads taking advantage of the wire characteristics.

Table 1 Draft specification of a 1kA-current lead [5]

Rated current (A)	1000
Size (mm)	340 x 54 x 60
Distance between electrodes (mm)	200
Temperature range (K)	77 – 4.2
External magnetic field (T)	0.5
Thermal conductivity (W)	≤0.3
Structure	350 A class x

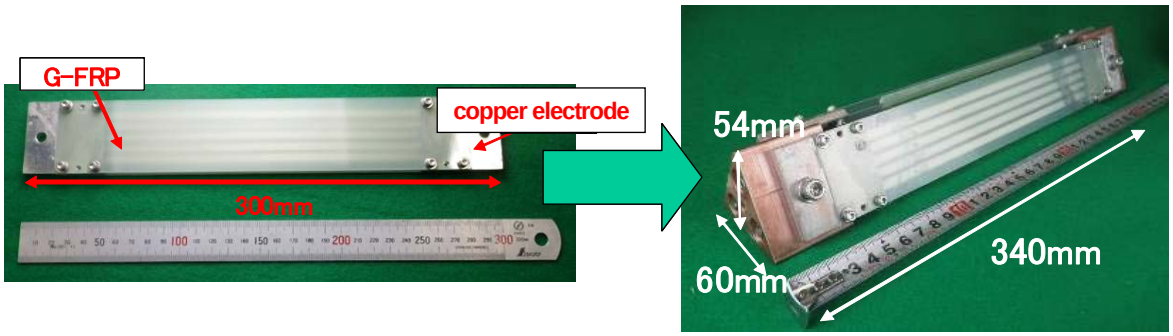

Fig. 1 Prototype 1kA-current lead [5]

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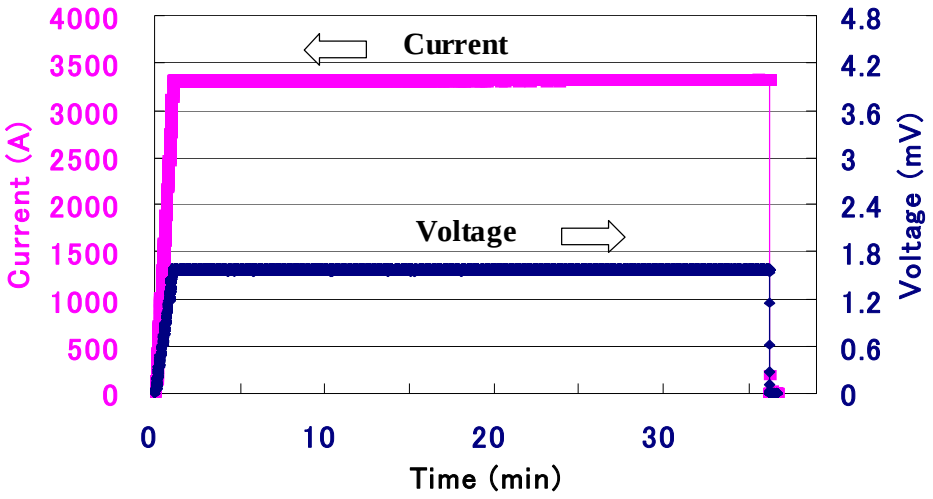

Fig.2 Continuous current application-testing results [5)]

References:

1. Toshio Kawahara et al., 2012, The 73rd Japan Society of Applied Physics Autumn Meeting.
2. Y. Yamada *et al* : IEEE Trans. Appl. Supercond., Vol. 21 pp. 1054 – 1057 (2011).
3. Kazunari Kimura *et al.*, 2012 Autumn Conference o f the Cryogen ic and Superconductivity Society of Japan, 1A-a07 (2012).
4. Haruki Motohashi *et al.*, Summary of T echnical Papers of 2012 Autumn Me eting of Cryogenic and Superconductivity Society of Japan, 1B-a02 p. 19 (2012).
5. Toru Takahashi *et al*., 2013 Autumn Conference of the Cryogenic and Superconductivity Society of Japan, 2P-p29 (2013).

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Feature Article: Refrigeration and Cryogenic Technologies - Thermally Insulating Concentric Double-Pipe and Cryogenic Cooling System for Superconducting Cables

Sataro Yamaguchi, Professor
Hirofumi Watanabe, Associate Professor
Center of Applied Superconductivity and Sustainable Energy Research
Graduate School of Engineering, Chubu University

Chubu University will join in the construction of a direct-current superconducting cable facility designed for direct-current power transmission systems intended for a data center in operation at Ishikari City, Hokkaido. The construction will be undertaken in collaborations with Chiyoda Corporation, Sumitomo Electric Industries, Ltd., and SAKURA Internet Inc. with the budget provided by Ministry of Economy, Trade and Industry. In this project, referred to as the Ishikari Project, two cable systems lengths of 500m and 2000m will be fabricated. The fundamental concept of the construction is aimed towards the future fabrication of longer cables produced at lower costs, and investigations thus far include the design standardization and utilization of LNG exergy in cold temperature. The following account provides a summary regarding the fundamental makeup of a thermally insulated concentric double-pipe, and a proposal regarding the utilization of LNG cold exergy.

Return pipe assembly

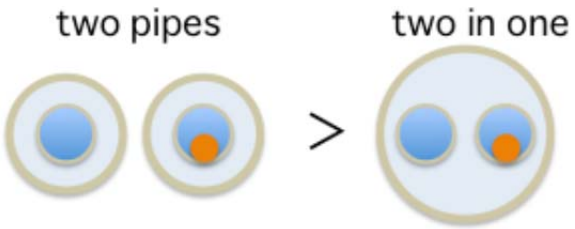

Fig.1 Fundamental make-up of the thermally insulating double pipes: Low thermal conductivities are measured when two cryogenic pipes are enclosed within a single vacuum pipe

Superconducting cables have a coaxial structure with each having their own go-and-return conductors. As this system will be practically deployed, a return pipe is necessary since the transmission and receiving ends are separated. Refrigerator thermal loads are made up of the sum of thermal loads from the cryogenic pipe housing the cable and the return pipe, and the aim is to reduce these to a minimum. Figure 1 shows the cross sections of two types of pipes. Whilst the outer pipe sits at normal temperature and is used to sustain the vacuum, liquid nitrogen coolant flows through the inner pipe, where one of them also houses the HTS cable. The figure on the left shows two normal temperature pipes concentrically housing two cryogenically cooled pipes. The figure on the right shows two cryogenic pipes housed within a single normal-temperature pipe. Radiant heat investigations have determined the thermal conductivity is low for the structure shown on the right hand side of the figure, and are understood to be due to the cryogenic pipes shielding each other from their normal temperature wall surroundings. It is also suggested that this

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arrangement will enable th e realization of cheaper manufacturing in the fu ture. It is deter mined that the on-site welding of the inner pipe will be necessary and therefore, the employment of on-site welding robots is now under investigation in an attempt to improve welding reliability.

Since the two cryogenically cooled pipes have the same flow volume and one is used to house the cable, the diameter of return pipe is designed having a slightly smaller dia meter. In order to keep manufacturing costs at a minimum, the plans are to ha ve an exte rnal galvanized ir on pipe enc losing a stainless steel cryogenically cooled pipe. Flow volumes of up to 40 L/min and pressure losses of up to 0.1 MPa are assumed for a 2000 m-lon g cable, us ing straight-length plumbing pipes to minimize coolant circulation pressure losses over such long distances. It is therefor e possible that circula tion will be realized utilizing current available pumps.

For the vacuum pumping system, the plans are to utilize vacuum pumps installed at the both ends of the cable terminals. Exhaust speed is estimated to be up to around 50 0 L/s with the use of a turbo-molecular pump. However, the exha ust time will be significantly dependent upon the out gassing volume of the conductance and the multi-layer insulation (MLI). Therefore, in terms of practicality, the plan is to install an additional vacuum pump at the cable midpoints and achieve an exhaust time of around one week at max.

Utilization of LNG cold energy

LNG is composed mainly of methane at temperatures of around 113 K, and being only 40 K hig her than liquid nitrogen temperatures. Investigatio ns to employ the exerg y in cold temperature as a way to sustain superconducting cables at cryogenic temperature and at low costs are ongoing. A simple study has confirmed that the refrigerator COP incre ases to around 0.2-0.3 during a 300 K-77 K heat cy cle. This is some five times improve ment compared to around 0.067 achieved by curr ently available Stirling cryocoolers. If realized, economic improvements of a large-scale system will be attainable.

At present, Japan has 25 LNG station locations and is the world's largest importer. Despite this, more than 90 % of the LNG exergy in cold temperature is dumped. The majority of LNG is utilized for fuels at power plants located close to high-electricity consuming urban areas such as Tokyo Ba y, Osaka and Nagoya. Exploiting LNG exergy for superconducting power tr ansmission technology is logi cal in this respect. Utilization of LNG exergy for super conducting applications is considered to be the future model standard. Desk studies are underway to improve refri gerator COPs and further develo pment is anticipated for a refrigerator utilizing LNG exergy.

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