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Newsletter on the Latest Technologies Developed by RTRI

Railway Technical Research Institute
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GENERAL INFORMATION

ARTICLES

Foreword

Katsuji AKITA
President

It is now eighteen years since the foundation of Railway Technical Research Institute (RTRI), an organization for railway research and testing operations, as part of the reformation of the former Japanese National Railways.

RTRI has made great contributions to the speed-up of the Shinkansen and conventional railways, as well as to the improvement in seviceability and safety of railway systems, etc. It has also played a major role in investigating the causes of natural disasters (earthquakes, etc.) and railway accidents and in providing technical support for measures to prevent such. In addition, RTRI has been working on the joint development of maglev with Central Japan Railway Company (JR Central). Last year, the national committee concluded: "Key technologies for putting maglev into practical use have been established." Thus, RTRI and JR Central have attained the goal of the development of maglev technology.

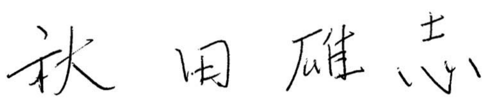
Railways of the 21st century are not only required to have the characteristics of railways (high speed, large capacity, safety, stability). Technological innovations are also required of them from a social standpoint, such as providing diverse new services to users and improving the response to global environmental problems.

In taking office as president of RTRI, I put up the following as the keywords for the activities of RTRI in the years ahead.

- Contribution to society by means of railway technologies
- Creation of railway technologies for the 21st century
- Base for the interchange of technologies

This year marks the start of RESEARCH 2005- the master plan that formulates the five-year activity policy of RTRI. In order for RTRI to contribute to society, including the railway companies, it is vital that we not only carry on steady, fundamental research activities but also positively tackle technology development from a new standpoint to bring about innovations.

Appointed to the post of president last April, I have assumed the heavy responsibility of steering RTRI at this time as it takes a bold leap. I am determined to fulfill my responsibility with all my might.



Reorganization to Respond to the New Master Plan

Hideo KIYA
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As already publicized in the March 1, 2005 issue of Railway Technology Avalanche, RTRI started its master plan RESEARCH 2005 in April 2005. At the start of this new master plan, we decided to make a partial change to our organization in order to properly respond to the changes in the conditions surrounding RTRI after 2000 when the previous master plan was formulated. The purpose of the reorganization was to concentrate the capacities of RTRI and carry out effective R&D, giving due consideration to compatibility with the previous master plan. The main points in the present reorganization are described below. The new organization of RTRI is schematically shown in Fig. 1.

1. Abolition of Maglev Systems Development Department and Installation of Maglev Systems Technology Division

Concerning the maglev technology development project that has been in operation since FY 1990, it was confirmed in FY 2004 that the key technologies for putting maglev into practical use had been established. It was decided, therefore, that R&D on maglev should now be focused on applying superconducting technology, linear motor technology and other technologies and know-how that have been developed thus far to conventional railways. To that end, the Maglev Systems Development Department, which played a leading role in the development of maglev technology, was abolished, and the Maglev Systems Technology Division was newly created. The Maglev Systems Technology Division includes several study groups and Yamanashi Maglev Test Center.

2. Reorganization of Information & International Affairs Division

RTRI had an Information & International Affairs Division, which was in charge of information transmission/reception and international affairs. However, in order to respond more properly to the changing situation, such as the growing state of information networks within society and the increasing volume of work related to international standards, the former division was reorganized, and divided into the Information Management Division and the International Affairs Division.

To respond speedily and properly to the information networks in society, the Information Management Division exclusively takes care of utilization of the Internet, security and personal information management, as well as the conventional information management and information transmission/reception. Therefore, in addition to the existing Network Systems Management, Technical Information Services, Intellectual Property, etc., a Health Insurance Systems Center is included in the Information Management Division.

Concerning the International Affairs Division, in addition to the existing International Affairs responsible for coordination and promotion of international operations, an Information Standards Center in charge of international standards is newly installed to ensure the smooth, efficient execution of international operations.

3. Wind Tunnel Technical Center

The administration of the Wind Tunnel Technical Center that maintains and manages the large, low-noise wind tunnel of RTRI was transferred from the Administration Division to the Research & Development Promotion Division. The purpose of the transfer is to facilitate the adjustment of plans for use of the wind tunnel by RTRI divisions and outside organizations, and to reinforce and make smooth the management of testing and measuring facilities.

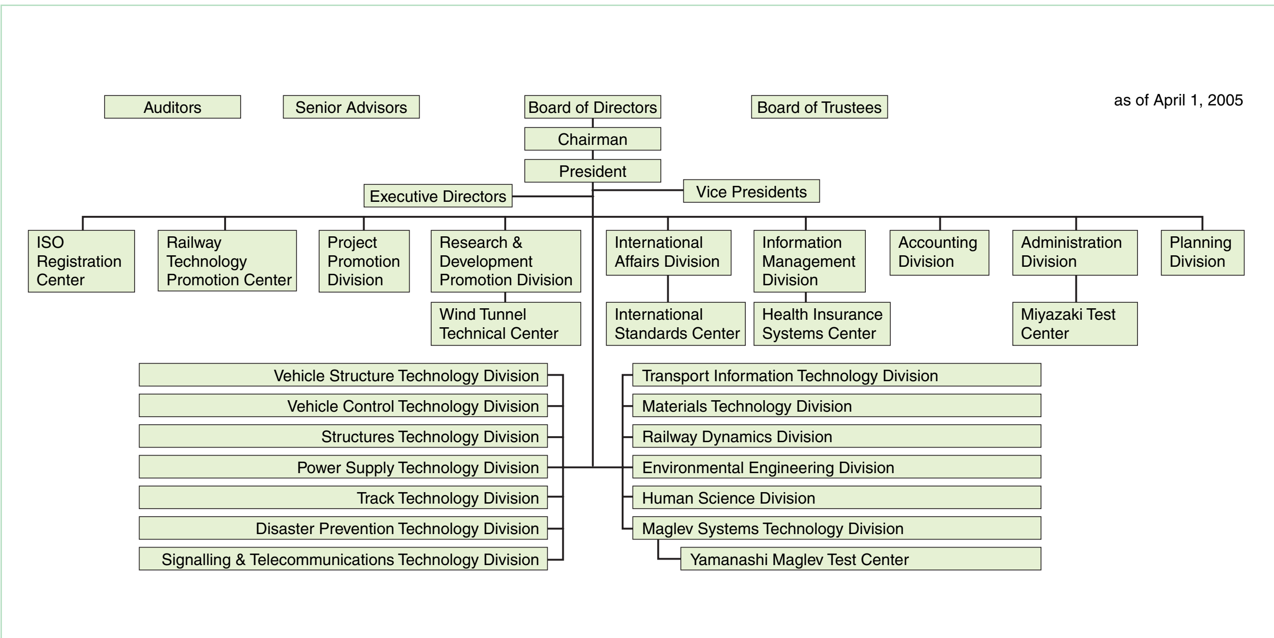

Figure 1. Organization of RTRI

A New Train Position Detection System Using GPS

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Railways in Japan have many sections in which there is a succession of sharp curves. In order to permit the trains to negotiate those curves at higher speed, a controlled tilting train was developed and put into operation. The controlled tilting train has contributed much to improvements in passenger services, including shorter traveling time. Although proactive R&D on the hardware of tilting trains has been carried out, the software (the method used to detect the current positions of trains) has remained unchanged. Working with these conditions, we have come up with a new train position detection system using GPS-a system that is not dependent on such ground markers as the ATS (automatic train stop) ground coil, and which offers a positioning accuracy equal to or higher than the conventional system.

Accurately detecting the current position (calculating the longitude and latitude) of a train by GPS in a mountainous area, tunnel or urban area is so difficult that it is necessary to supplement the conventional detection method with another method. In this respect, we worked out a data reception reliability coefficient as an index of positioning accuracy based on satellite information (number and arrangement of the satellites involved) and decided to perform one of three different types of data processing according to the value of that coefficient (Fig. 1). Our system detects the current position of a running train by using in combination the advantages of these three methods: ① GPS data, ② track curvature and ③ wheel rotating pulse count by tachometer generator. The GPS, which offers absolute coordinates, cannot be used at places which are out of reach of radio waves. Besides, depending on signal reception conditions, the accuracy of positioning by GPS deteriorates markedly. The track curvature can be checked easily since it has good repeatability. Even so, it is necessary to give a point at which to start the checking. The wheel rotating pulse count by a tachometer generator offers a high positioning accuracy in short sections. But even in this case, it is necessary to give a point at which to start counting. The three different methods of position detection used by our system have characteristics that are complementary to one another. By utilizing the advantages of the three methods in combination according to the accuracy of positioning by GPS, it is possible to build a train position detection system that is accurate and stable. The system configuration is shown in Fig. 2.

Collation of the measured curvature with the curvature map is performed as follows. First, the current position is roughly determined from the GPS data or the wheel rotating pulse count by the tachometer generator, and that position is taken as a tentative current position (Fig. 3). Next, with the tentative current position as the initial value, data relating to the sections before and after that position are extracted from the curvature data (curvature map) that has been obtained during a preliminary run. Then, the curvature data for section a[m] immediately before the current position observed during the run is compared with the extracted portion of the curvature map. The true current position is obtained by shifting the tentative current position till the point at which the two data coincide with each other is found.

For the purpose of verifying the accuracy of position detection by our system, the results of position detection obtained during a train run through 15 fixed points on the ground were extracted (Fig. 4). As a result, it was confirmed that our system had a positioning accuracy equal to or higher than the conventional system, with the positioning error being within ±4 m.

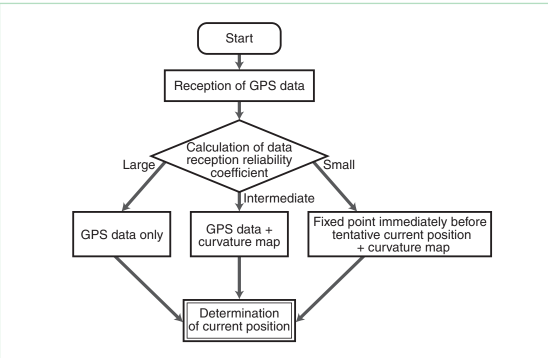

Figure 1. Flow of data processing for position detection

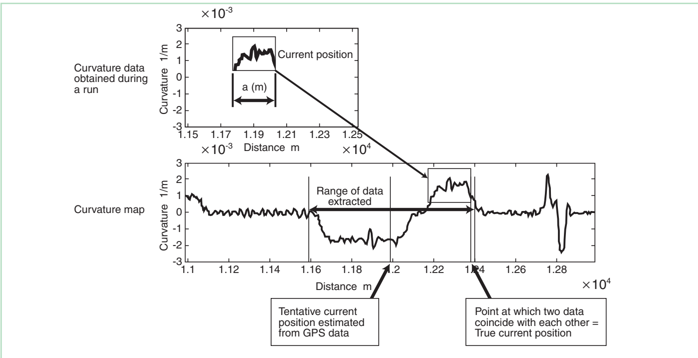

Figure 3. Collation with curvature map

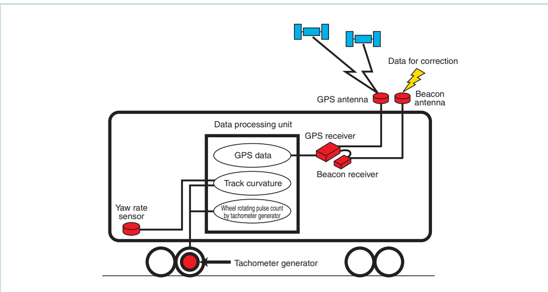

Figure 2. System configuration

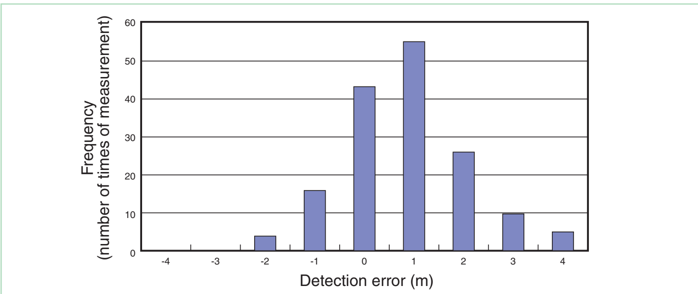

Figure 4. Detection error distribution

Investigation into Suppressing the Bending Vibration of Railway Vehicle Carbody with Piezoelectric Elements

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Recent railway vehicles are being made increasingly lighter in weight, allowing for an increase in train speed. This in turn contributes to improvements in promptness, the saving of energy, etc. On the other hand, there are cases in which the vertical bending vibration of carbodies becomes conspicuous, due mainly to a decrease in their rigidity and damping. This vibration often occurs in the frequency range to which human beings are very sensitive. Since the vibration causes passenger comfort to decline, effective measures to suppress it are increasingly called for.

Under that condition, RTRI has proposed various measures to suppress the bending vibration of carbodies. Some of those measures have already been put into practical use in commercial vehicles. In the future, however, it is expected that the demand for speed and riding comfort will become stronger. It is, therefore, necessary for us to propose, in addition to the measures we have developed for railway vehicles of conventional construction, a new measure that permits suppressing the bending vibration of carbodies more effectively while reducing the carbody weight still more, through the introduction of new materials, new functions and control technology. In this context, the author et al. are developing a new vibration suppression technique that utilizes piezoelectric elements, which are electrically shunted by an external circuit (shunt circuit). We aim to apply our new technique to suppressing the bending vibration of railway vehicle carbodies.

Typically, the piezoelectric element generates a voltage when subjected to strain. Piezoelectric elements are used to suppress the bending vibration of carbodies as follows. When the vibration occurs as shown in Fig. 1, a strain is produced in the piezoelectric elements attached to the carbody as the carbody is deformed. As a result, a voltage is generated. When a shunt circuit including a resistor is connected to the elements, the voltage generated by the elements causes a current to flow to the circuit. As the current flows through the resistor in the shunt circuit, the electric energy is dissipated in the form of Joule heat. In this way a loss of energy occurs. Since the electric energy was originally produced by the bending vibration of the carbody, the energy loss has a damping effect on the carbody, thereby suppressing the bending vibration.

Before applying the above technique to an actual vehicle, we attached a total of eight piezoelectric elements (each measuring 155 mm x 40 mm x 3 mm), four on each of the right and left side beams of a 1:5 scale model of Shinkansen car 4.9 m in overall length and about 300 kg in mass as shown in Fig. 2 (photo at left), and subjected the model to a stationary vibration test using an electrodynamic shaker to confirm the vibration-suppressing effect. The frequency response between excitation force and carbody center acceleration is shown in Fig. 2 (diagram at right). Although the total mass of the elements was approximately 1.1 kg, or only about 0.4% of the mass of the model, the amplitude of bending vibration decreased to less than one-half.

In the future, we intend to study methods for attaching the elements to actual vehicles and carry out performance confirmation testing (stationary vibration test and running test) after estimating the required number of elements, predicting the damping performance of elements, etc. using a simulation model, in order to put the new technique into practical use.

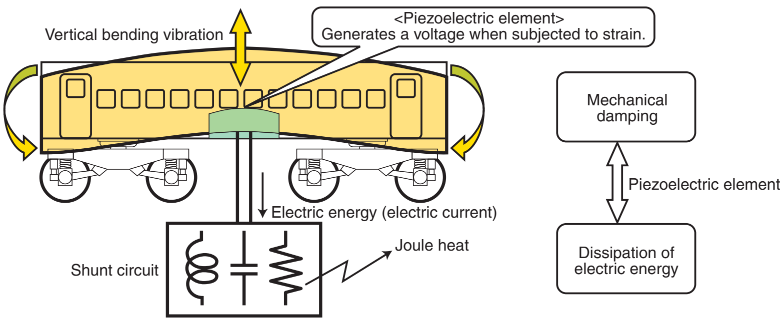

Figure 1. Scheme of bending vibration suppression technique using piezoelectric element and shunt circuit

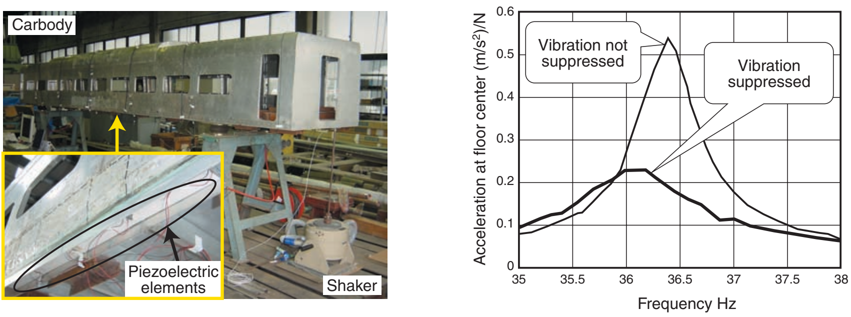

Figure 2. Scene of vibration test with 1:5 scale model of Shinkansen car (left) and results of vibration test (right)

Development of Low Cost Long Life Antilock Brake System for Freight Trains

Kiyoshi KAWAGUCHI
Senior Researcher, Traction Control, Vehicle Control Technology Division

1. Reasons for our freight train ABS development

Because freight train brake systems must be able to operate without an electric power source, freight trains normally use low-cost automatic air brakes that meet international standards. Freight trains in Japan run on the same track as passenger express trains, so they must have brake systems whose response and deceleration are higher than those of freight trains anywhere else in the world. However, this means that the wheels of high-speed container trains in Japan are susceptible to wheel slide damage, similar to that of the wheels of electric passenger trains.

Therefore, Japanese freight trains with no electric power source have long presented significant problems, the two most important being: (i) a rise in noise levels due to vibrations caused by wheel-flat; and (ii) an increase in maintenance costs for wheels and bearings.

To permit maintenance savings for high-speed container trains, as well as lower costs for operating high-quality freight services, we recently developed a new type of Antilock Brake System (ABS; also called Wheel Slide Prevention [WSP]).

2. Configuration of ABS for freight trains

The newly developed ABS for freight trains has the following features.

(1) Since the freight train has no electric power source, a small generator is installed on the axle end, to generate electricity while the train is running (Fig. 1).

(2) The generated electricity is stored in a special electric double-layer capacitor (EDLC), which is barely affected by outdoor temperatures (Fig. 2).

(3) In order to reduce generator and EDLC costs, anti-skid valve power consumption is minimized.

The configuration of the ABS for freight trains is shown in Fig. 2.

3. Key development points

3.1 Long life EDLC for freight trains

We developed the first-of-its-kind EDLC (diluted sulfuric acid solution-based electrolyte, 24V, 5 F; see Fig. 3). By sealing 28 cells in an oblong ceramic vessel, we were able to achieve high reliability, long life and high voltage (24V) under varying outdoor temperature conditions.

Homogenous cells are stacked in the form of sheets to eliminate the need for a cell balancing circuit and thus cut EDLC production cost. Exterior dimensions are 72×148×84 mm, and the weight is 1.6 kg including the vessel. The results of accelerated durability tests show that the EDLC life cycle is much longer than the development target, which was 8 years, and is now actually estimated at more than 30 years (calculated after even considering operating temperatures below -20°C and above +65°C).

For reference purposes, a conventional EDLC uses an organic electrolyte and is enclosed in a cylinder made from aluminum sheeting. Its life cycle is only several years under outdoor conditions.

3.2 Energy-saving antiskid valve

Two effective ways to cut freight train ABS costs are to significantly reduce the power requirement and capacity of both power supply and charge units. Reducing the power consumption of the antiskid valve is the most effective method.

We therefore developed a new energy-saving control method (Fig. 4) and a new valve structure (Fig. 5). We reduced power consumption of the anti-skid valve to 2.2 W per set. This is much lower than the development target, which was 1/10th that of a conventional valve - actual power consumption is 1/60th that of a conventional valve.

The air inlet and outlet are covered with dust filters, and the valve structure has no parts susceptible to friction, to reduce wear and tear. This ensures a maintenance-free period of eight years, which was our development target.

4. Future plans

The results of various tests show that the freight train ABS has attained most development targets, including a cost reduction to one-half that of conventional models. Tests will be continued for some time, with a view to putting the new ABS into practical use for next-generation container trains.

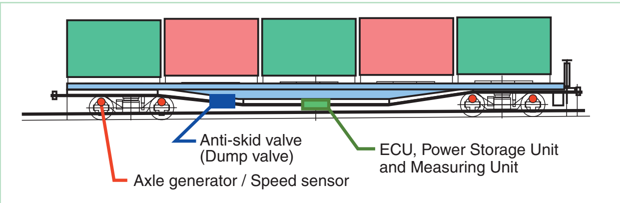

Figure 1. New ABS mounted on container freight car.

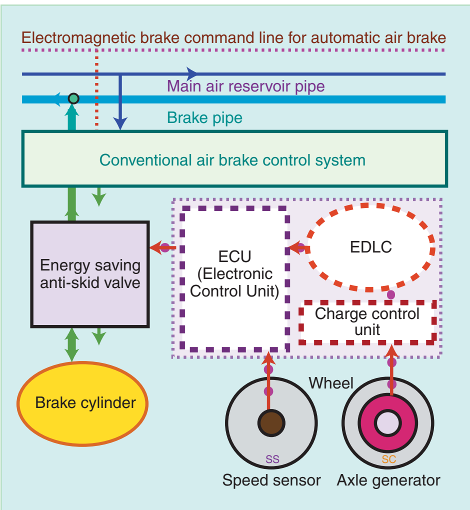

Figure 2. ABS configuration for freight trains (example).

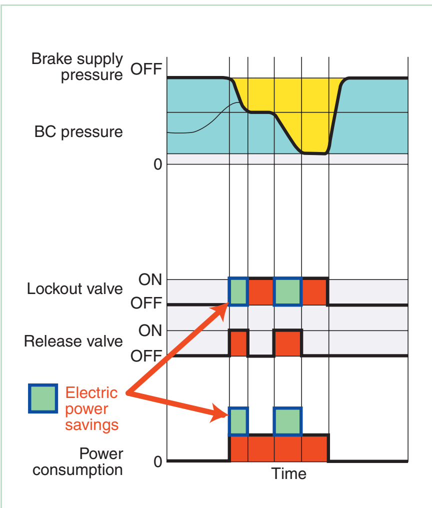

Figure 4. Energy-saving control method used by anti-skid valve

Figure 3. Long-life EDLC for freight trains

Figure 5. Energy saving anti-skid valve

Development of a New Superconducting Main Transformer for Trains

Hiroshi HATA
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In view of the recent increase in capacity of high-temperature superconducting wire rods, the Railway Technical Research Institute has developed a superconducting main transformer for trains and tested it. The purpose of the development was to reduce the size and weight of main transformers and improve their efficiency. A bismuth-based superconducting tape wire was used for each of the windings of the test-manufactured main transformer. The windings are immersed in liquid nitrogen. On the assumption that the new main transformer should be applied to Shinkansen trains, the winding voltage was decided to be 25 kV for the primary winding, 1,200 V for the secondary windings (4) and 440 V for the tertiary winding. In order to reduce the AC loss, a core-type transformer whose windings are solenoid coils was adopted. To reduce the refrigerator load, the core was set in a normal-temperature space. The refrigerator is supposed to keep the temperature of liquid nitrogen at -207 °C.

The transformer measures roughly 1.2 m in width, 0.7 m in depth and 1.9 m in height (excluding the compressor). This time, a floor-mounted type was test-manufactured as the first step of the development. It has a mass of 1.71 tons (excluding the refrigerator and compressor).

The newly-developed main transformer for railway vehicles was subjected to a type test in accordance with JIS. As a result, it was confirmed that the maximum capacity of the transformer under superconducting conditions is equivalent to 3.5 MVA. With the new transformer, it is possible to pass a current of 750 A through the secondary windings. The overall transformer capacity corresponds to 4 MVA. The superconducting transformers that have been test-manufactured in the past have a maximum capacity of 1 MVA or so. The new transformer having a far greater capacity has demonstrated that it has almost attained the level required of world-class high-speed trains, such as Shinkansen, TGV and ICE. In addition, the new transformer showed no abnormal conditions even in an AC withstand voltage test at 42 kV for 10 minutes and a 150 kV lightning impulse test, proving that it had no problems with electrical insulation. From test results, the AC loss was estimated to be 7.9 kW at 4 MVA. The reason for this is that the AC loss of the wire is 5 to 10 times greater than the theoretical value. At the present time, therefore, the new transformer, with the extra mass of the refrigerator, has no special advantages over existing transformers. However, if the AC loss could be reduced to near to theoretical value, it can be expected that the mass would decrease by some 20% and the efficiency would improve to 99% or more. In the future, we intend to focus on reducing AC loss and developing a light, large-capacity refrigerating system.

The present study was carried out with a subsidy from the Ministry of Land, Infrastructure and Transport.

Figure 1. Appearance of the test-manufactured superconducting main transformer

Table 1. Specifications of the test-manufactured superconducting main transformer

Primary voltage	25kV
Secondary voltage	1,200 V (4 windings)
Tertiary voltage	440V
Frequency	60Hz
Winding material	Bi-2223 tape wire
Reactance matrix	Comparable to existing main transformers
Installation site	Floor
Refrigerant	Liquid nitrogen