OCS Inspection System for High-Speed Railways

Yoshiharu Katada,
Seiji Tabayashi

Keywords High-speed railways, OCS inspection, Image analysis

Abstract

The Overhead Catenary System (OCS) Inspection System is used to check the conditions of the laying and wear of contact wires indispensable for safe operation of electric railways. Meiden OCS Inspection System, CATENARY EYE, is a product using digital cameras, our image analysis and processing technologies. It can perform a high accuracy non-contact inspection of the OCS. We recently installed and delivered our systems to high-speed railways: JR Kyushu Railway Company ("JR Kyushu") and Taiwan High Speed Rail Corporation ("THSRC"). In 2003, we delivered the first model of CATENARY EYE to JR Kyushu before the Kyushu Shinkansen Line was inaugurated between Shin-Yatsushiro Station and Kagoshima Chuo Station. Afterwards, in 2010 we shipped a new OCS Inspection System with an additional contact wire wear measurement function. We installed these systems on the 800 Series Shinkansen commercial vehicles that had been newly produced in time for the inauguration of the entire line between Hakata Station and Kagoshima Chuo Station. In 2013, our new OCS Inspection System was delivered to the THSRC. It was for the 700T Series commercial vehicles for the section between Taipei Station and Zuoying (Kaohsiung) Station.

1 Preface

The Kyushu Shinkansen Line was partially inaugurated in 2004 between Shin-Yatsushiro Station and Kagoshima Chuo Station. Along with this partial inauguration, JR Kyushu Railway Company ("JR Kyushu") had to have inspection equipment for the maintenance of the catenary system.

At that time, we released image-analysis applied products and received an inquiry about the application of such products to the Shinkansen Line. In this connection, we developed and delivered in 2003 a non-contact type Overhead Catenary System (OCS) inspection system using digital cameras, our applied image analysis, and processing technologies. At that time, however, the delivered system did not have any function for measurement of wear on contact wires. It only had a function to measure and check the contact wire height, stagger, gradient, hard spot, and obstacles.

In 2006, we commercialized a function to measure wear of contact wires by using our image analysis and processing technologies. In order to meet the deadline for the inauguration of the entire line between Hakata Station and Kagoshima Chuo Station on March 12, 2011, we delivered a new system which provided an additional wear measurement function for newly produced commercial vehicles. Fig. 1 shows commercial vehicles for the Kyushu Shinkansen.

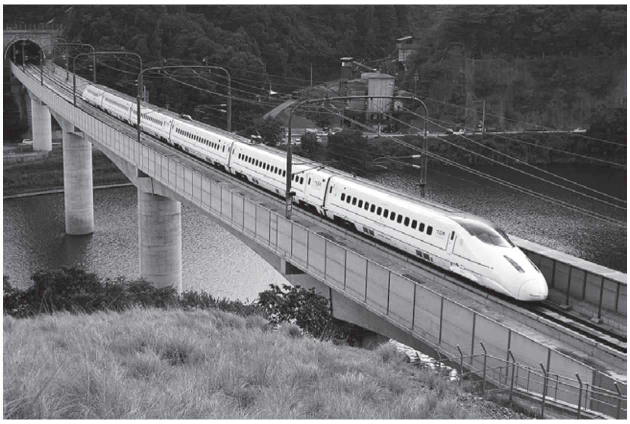

Fig. 1 Commercial Vehicles for the Kyushu Shinkansen

Commercial vehicles of the Kyushu Shinkansen are shown, where the Meiden OCS Inspection System is loaded.

Fig. 2 Commercial Vehicles for the THSR

Commercial vehicles of the THSR are shown. It uses Meiden OCS Inspection System.

The Taiwan High Speed Rail (THSR), a high-speed rail line, was meanwhile inaugurated in 2007 between Taipei Station and Zuoying (Kaohsiung) Station. At that time, however, the operating company, Taiwan High Speed Rail Corporation ("THSRC"), did not have any full-scale OCS inspection system.

In 2013, we delivered the first product for an overseas version, CATENARY EYE, to the THSRC. Fig. 2 shows commercial vehicles for the THSRC. This paper introduces respective features and differences in each system for the Kyushu Shinkansen Line and the THSR Line.

2 System Configuration

When installing any equipment in commercial vehicles of high-speed railways, the most important consideration is the method of installation on the rooftop. For both Kyushu Shinkansen and THSR, vehicles are operated at an ultra-high speed. Therefore, the structure on the rooftop is devised to reduce the effect of a pantograph lifting force and noise around the railway line to the lowest possible level.

The top speed of the Kyushu Shinkansen is 260km/h and of the THSR is 300km/h, respectively. Modification of vehicle structure and installation of irregular shaped equipment are not allowed because aerodynamic characteristics and/or noise-related factors may change. For this reason, we met often with railway companies and service providers of vehicle modification work. In so doing, we determined the equipment installation method by frequently amending the loading position adjustments in scale of millimeters.

Our rooftop system is designed for installation on many types of vehicles, from road-rail vehicles to

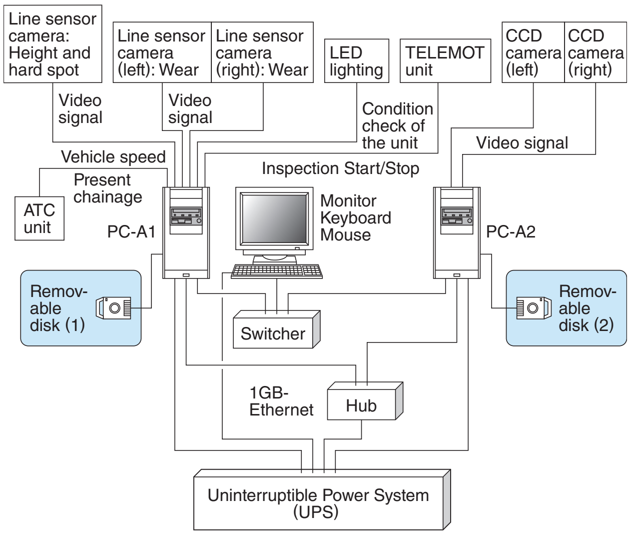

Fig. 3 Outline System Configuration

An outline system configuration is shown. Our system is installed on a Kyushu Shinkansen commercial vehicle.

Fig. 4 Rooftop Equipment

A view of a Kyushu Shinkansen train with the rooftop system is shown.

commercial vehicles on high-speed railways. The system is equipped with cameras, lighting units, signal cables to feed power to these units, signal cables to send camera images to a vehicle interior computer system, and boxes to contain these devices. Compared with the OCS inspection system for high-speed railways using laser, configuration of this new system is very simple and has a light mass. It can be loaded into a commercial vehicle without making a large modifications or decreasing the number of passengers.

Fig. 3 shows an outlined system configuration for the Kyushu Shinkansen, Fig. 4 shows a view of the rooftop system, and **Fig. 5** shows the interior system.

Fig. 6 shows system installations delivered to the THSR, **Fig. 7** shows the rooftop system, and **Fig. 8** shows the interior system.

A great difference in the rooftop system is that the 800-Series vehicle of the Kyushu Shinkansen has no cover for air-flow adjustment before and after a pantograph, while the 700T-Series vehicle of the THSR has such covers.

In the Kyushu Shinkansen, therefore, all equipment is loaded inside the roof so that there is no adverse influence on aerodynamic characteristics.

For the THSR, all equipment is accommodated in a cover on the roof except for part of lighting apparatus and cables. For the Kyushu Shinkansen, the condition shown in **Fig. 4** is always maintained during an OCS inspection or non-inspection period.

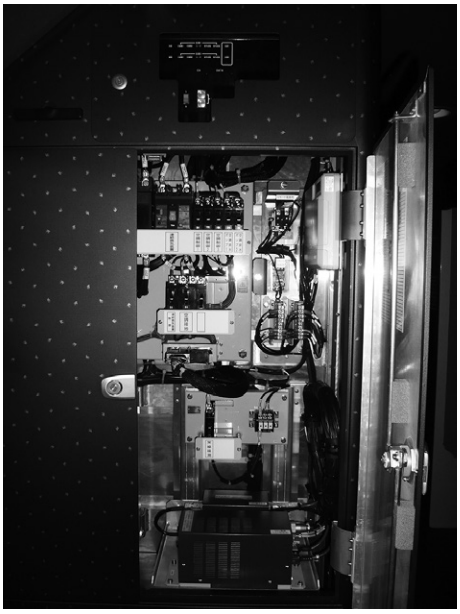

Fig. 5 Interior Equipment

Equipment is permanently installed in a specified location inside the commercial vehicle.

Fig. 7 Rooftop Equipment

A rooftop view of a THSR train with the rooftop system is shown. Since most of the equipment is accommodated in a cover for air-flow adjustment, the rooftop surface appears as the same with the normal vehicle without OCS inspection system and the differences are two windows: one for digital cameras and other for lighting.

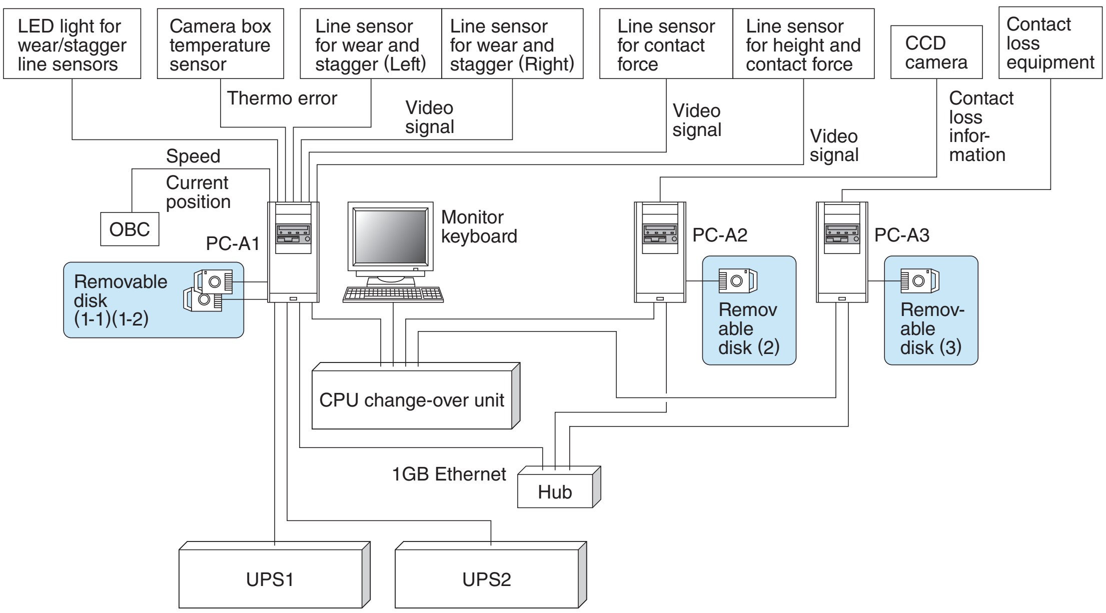

Fig. 6 Outline System Installations

Outline configuration of system is shown. It is installed in a THSR commercial vehicle.

Fig. 8 Interior System

Equipment is always installed in a specified location inside the commercial vehicle.

Fig. 9 Condition of the Rooftop during Non-Inspection

While inspection is not carried out, it is replaced with covers for preventing the camera and lighting windows from staining.

For the THSR, however, such a cover is exchanged during a non-inspection period to prevent contamination on the window for cameras and sensors. Fig. 9 shows the how it is covered during the non-inspection period and Fig. 10 shows the condition during an inspection.

As shown in Figs. 5 and 8, the interior system is permanently installed inside the vehicle for both Kyushu Shinkansen and the THSR. In regard to the installation space for the interior system, space consideration for the stowage of interior system was made at the vehicle design stage for both lines. In the case of the THSR, unused space for public telephones was utilized for the permanent installation of the interior system. The core of interior system contains a computer system and hard disks to save images taken during inspection. Compared to Japan, the average temperature is higher in Taiwan. Since there is no air conditioning in the equipment installation space, an external door is provided with a louver to produce air flows for cooling as a measure against overheating.

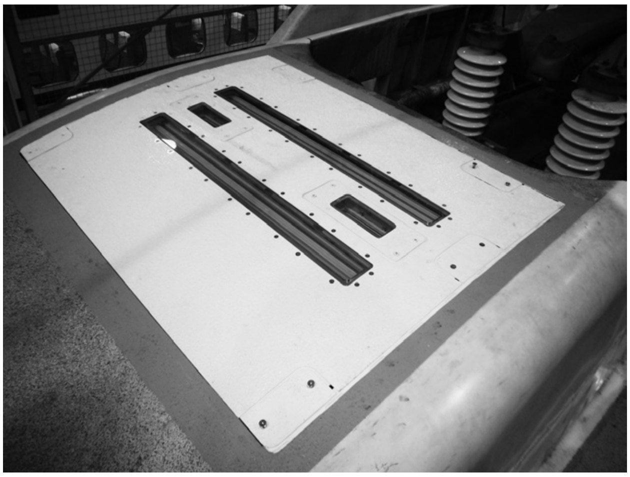

Fig. 10 Condition of the Rooftop during Inspection Service

While inspection is carried out, it is replaced with another type of cover that has open parts for cameras and lighting.

Table 1 Comparison of Functions

Comparison of functions is shown. It compares equipment for the Kyushu Shinkansen and the THSR. The circle means it has the function and no circle means it does not.

Function	Kyushu	Taiwan
Nighttime inspection	○	○
Daytime inspection		○
Remote inspection: Start/Stop	○	

3 Functional Specification and Features

Table 1 shows a comparison of functions available for the Kyushu Shinkansen and the THSR. The Kyushu Shinkansen is a system for nighttime inspection, while the THSR is a system for both daytime and nighttime inspection. (At the time when this system was first introduced to the Kyushu Shinkansen, functions for daytime inspection were not yet developed.)

The difference in daytime and nighttime

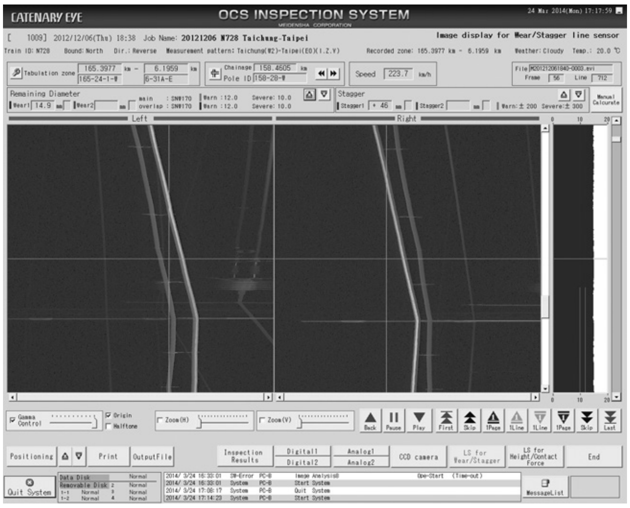

Fig. 11 Example of Wearing Surface Image during Nighttime Inspection

An example of an image is shown, observed during nighttime inspection. Since a gamma control function is used, conditions of the OCS structures can be observed. Without gamma control, the image will be black.

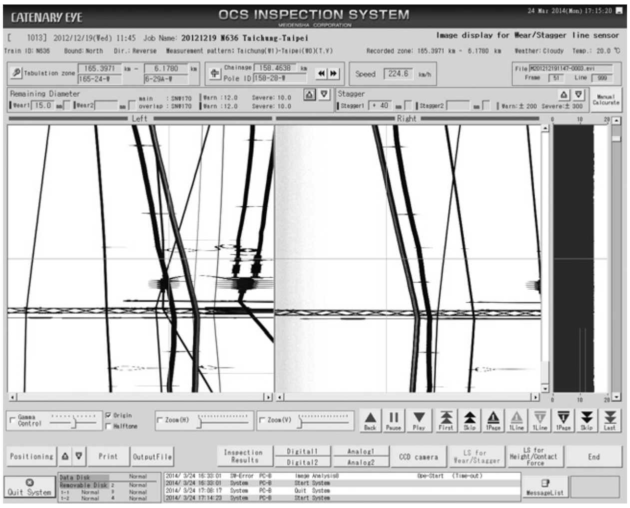

Fig. 12 Example of Wearing Surface Image during Daytime Inspection

An example of an image observed during daytime inspection in the same place as for Fig. 11 is shown. It can see the structure without gamma correction.

inspection is that nighttime inspection is less influenced by images other than those of the objects for target inspection, while images from daytime inspection can be influenced by glare (direct rays from the sun). In addition, in cloudy conditions, resultant images often appear to show a false surface, like wearing of the surface of contact wire. In such a case, analysis becomes very difficult to conduct.

From the viewpoint of the customer, the capability of daytime inspection leads to better working conditions for inspection services. In addition, the ability to clearly see background images (other than images of analytical objects) is required in the market as it contributes to the identifying of faulty spots. Fig. 11 shows an example of a wearing surface image during nighttime inspection and Fig. 12 shows an example of a wearing surface image during daytime inspection recorded in the same position. In order to conduct daytime inspections, it is necessary to provide for a large capacity of lighting compared with lighting in the nighttime. This is a considerable difference between daytime and nighttime inspection.

Table 2 shows a comparison of inspection items for both lines. In both cases, the basic functions are provided for the measurement of wear, height, stagger, and gradient. The difference in both systems is that the Kyushu Shinkansen is provided with the functions of hard spot and obstacle detection, while the THSR is provided with those of measuring contact loss and contact force which meets the Europe Standard.

Table 2 Comparison of Inspection Items

Comparison of inspection items is shown between equipment for the Kyushu Shinkansen and the THSR. The circle means it has the function and no circle means it does not.

Inspection item	Kyushu	Taiwan
Contact wire height	○	○
Contact wire stagger	○	○
Contact wire wear	○	○
Contact wire gradient	○	○
Hard spot	○	
Contact force		○
Arcing contact loss		○
Monitoring near pantograph	○	○
Monitoring obstacle near pantograph	○	

We made the worlds-first commercialization of a non-contact measurement for contact force through joint research with the Japan Railway Technical Research Institute (RTRI). Since this system can accumulate data of contact force and contact loss with a potential relationship during commercial operation of high-speed railways, correlation between contact force and contact loss, control values for the contact force, and such field data can be obtained. We believe that this system will contribute to the special management between contact wires and pantographs. In addition, we expect that this system will contribute to research on how a pantograph affects the progress of contact wire wear.

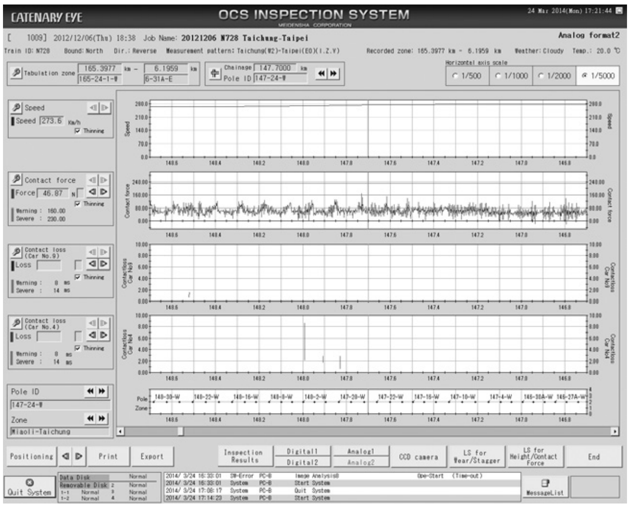

Fig. 13 Result of Contact Force Measurement (Chart Graph)

The chart graph second from above shows the contact force.

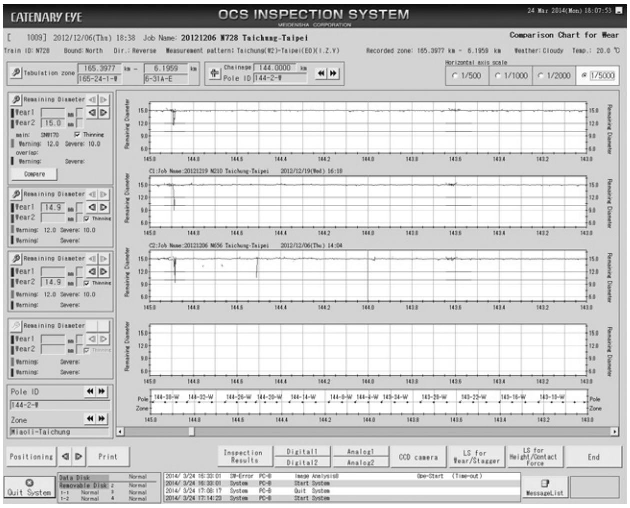

Fig. 15 Comparison of Wear

The latest residual diameter after wear can be compared with the result of former inspections (a maximum of 3).

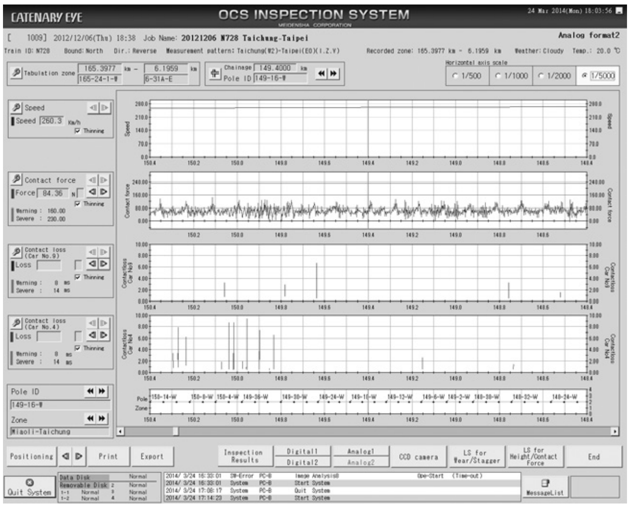

Fig. 14 Result of Contact Loss Measurement (Chart Graph)

The chart graphs, third and fourth from above, show the contact losses. Length of a line shows the intensity of voltage.

4 Result of Analysis

All analytical results from our OCS inspection system are mutually linked with actually measured images. It is, therefore, possible to pick up all the related data easily based on the noteworthy key data involving data exceeding control values from numerical information, charts, and image.

Fig. 13 shows the result of contact force measurement (in chart graphs) and Fig. 14 shows contact loss measurement (in chart graphs). The contact force is composed of an upward force to push up the pantograph (static push-up force) and an uprising force attributable to the lifting force of the pantograph. The total force functions as a force to push up the contact wire for a specified amount. A downward force is also effected as a reaction from the contact wire. As a result, the contact force may become less than "0" and contact loss appears between the pantograph and contact wire. A phenomenon of arcing occurs at a moment when this contact loss is caused. At that moment, an air gap is created between the contact wire and the pantograph where an arc current flows. With our system, ultraviolet rays with a specific wavelength contained in arcing sparks are detected and such arcing can be measured even in the daytime.

The contact loss data in Fig. 14 indicate the result of conversion of ultraviolet rays input into voltage. According to the intensity of arcing, voltage varies widely. These data closely correspond to the condition of wear in contact wires and the remaining diameters of contact wires, and can be checked with a single action. In regard to the remaining diameters of contact wires for Taiwan, it is made possible to make comparison with any former data. Fig. 15 shows a comparison screen for the remaining diameters of contact wires.

5 Remote System Operation of Start and Stop

For the Kyushu Shinkansen, remote start of inspection, remote stop of system, and the remote monitoring of equipment malfunction is possible.

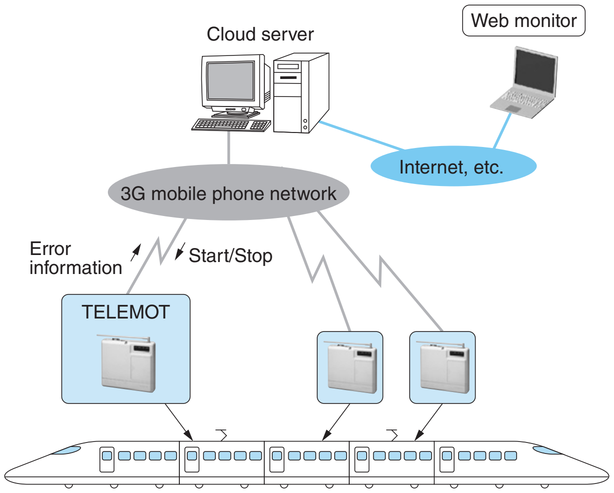

Fig. 16 Outline System Configuration for Remote Operation

Remote operation is performed by using our cloud server service and TELEMOT.

These functions can be made available by our cloud computing service and a wireless monitor control terminal made by Meiden, TELEMOT, using a 3G mobile network provided by "au" (service brand name of Japanese communications carrier, KDDI Corporation). **Fig. 16** shows an outline configuration for remote operation.

6 Postscript

For safe and stable operation of high-speed railways, it is extremely effective to use a high-accuracy OCS inspection system that can be loaded on a commercial vehicle. The use of various data obtained from the commercial vehicle is an important key to contact wire maintenance for switching from conventional Time Based Maintenance (TBM) to Condition Based Maintenance (CBM). Going forward, we will work on an even more accurate and stable inspection system. In so doing, we would like to contribute to the safe and stable operation of high-speed railways.

Lastly, we would like to express our sincere gratitude to JR Kyushu and THSRC and all product-related people for their kind suggestions and cooperation during the development of our OCS inspection systems for high-speed railways.