

# RTRI's Research and Development Continues to Contribute to the Evolution of Shinkansen



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## Introduction

The Tokaido Shinkansen marked its 60th anniversary on October 1, 2024. In FY2018, before the COVID-19 disaster, the total number of passengers across all Shinkansen lines is approximately 1.19 million per day. The Shinkansen is now an indispensable mode of transportation for business or sightseeing trips. The noteworthy success of the Tokaido Shinkansen has inspired the development and expansion of high-speed railway networks around the world. According to the International Union of Railways (UIC), as of October 1, 2023, there are high-speed railways with a maximum speed of 200 km/h or more in 21 countries and regions around the world, covering a total distance of 59,498 km<sup>1)</sup>. It is no exaggeration to say that the Tokaido Shinkansen has truly changed the way railways are operated around the world.

The Railway Technical Research Institute (RTRI) has been committed to the realization of the Tokaido Shinkansen and has been working to solve new technical problems since the launch of the Tokaido Shinkansen service. In a huge transport system like the Shinkansen, it is necessary to effectively inte-

grate many key technologies, such as rolling stock technologies for safe and stable running, technologies to ensure safety even during earthquakes, and technologies to cope with noise that increases as speed rises. This article covers some of these technologies to which RTRI's large-scale test facilities and analytical capabilities have contributed since the Japanese National Railways (JNR) was divided and privatized.

## Evolution of Rolling Stock —The advent of bolsterless bogies—

When the Tokaido Shinkansen started its operation, the 0-Series trains had a maximum operating speed of 210 km/h. The 100-Series trains were introduced in 1985 for the Tokaido Shinkansen, followed by the 200-Series trains with a snow-resistant structure in 1982 for the Tohoku and Joetsu Shinkansen and the fully remodeled 300-Series in 1992. The 300-Series incorporated a number of innovations developed during the final years of JNR's operations and the early years of privatization into JR companies. A noteworthy innovation were the bolsterless bogies\* that were adopted for the first time in Shinkansen trains. For the development of the bogies,

RTRI conducted running tests at the rolling stock test plant (*Rolling Stock Test Facility with a Vehicle for Shinkansen*) to confirm the running stability and vibration isolating performance of the bogies at high speeds. After running tests on the main line using the Central Japan Railway Company's 100-Series trains, RTRI was able to install bolsterless bogies with the 300-Series trains.

The adoption of bolsterless bogies and other technologies led to the successful weight reduction of the entire 16-car train from 970 to 710 tons for the 0-Series and contributed significantly to the realization of speeds up to 270 km/h. All Shinkansen rolling stock after the 300-Series utilized bolsterless bogies.

### \* bolsterless bogies

Bogies without bolsters, which transmit the load from the car body to the bogie frame. Without bolsters, the car body is directly supported by the air spring between the bogie frames. By eliminating the bolsters, the weight of the bogie is significantly reduced.



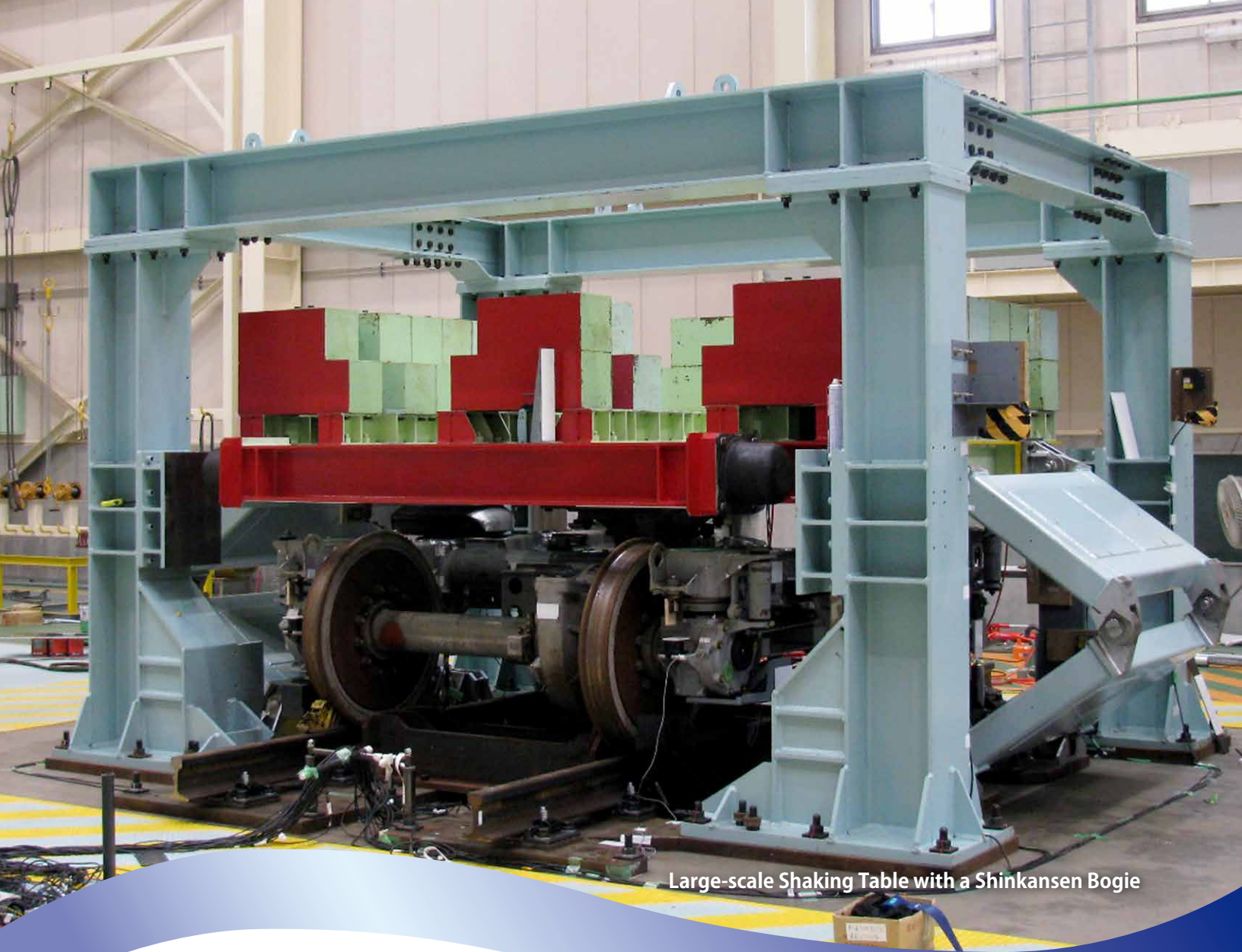
Rolling Stock Test Facility with a Vehicle for Shinkansen

### **Response to Large-Scale Earthquakes —Early earthquake warning system and derailment prevention measure for Shinkansen trains—**

In Japan, where large-magnitude earthquakes frequently occur, ensuring the safety of Shinkansen trains during each earthquake is a primary concern. Since Shinkansen trains run at high speeds, they cannot stop immediately even if emergency brakes activate. In contrast, the concept of the early earthquake warning system is to decelerate the train before the secondary wave (S-wave) arrives by using

the characteristics of the primary wave (P-wave), which has high velocity and low amplitude and travels through the ground first, followed by the S-wave, which is the principal wave. The Urgent Earthquake Detection and Alarm System (UrEDAS), which incorporates this concept, was introduced in the Tokaido Shinkansen in 1992. However, UrEDAS had problems in the accuracy of estimating seismic parameters (epicentral position and magnitude). After the 1995 Southern Hyogo Prefecture Earthquake, a new early earthquake warning system was introduced on the Kyushu Shinkansen, opened in 2004. This solved the problems

with the estimation accuracy by analyzing the large amount of data obtained from the earthquake observation networks developed by public organizations such as the National Research Institute for Earth Science and Disaster Resilience (NIED). This new warning system has been subsequently implemented on existing Shinkansen trains. In addition, an even more upgraded early earthquake warning system, which utilizes the ocean-bottom earthquake and tsunami observation networks developed by public organizations, has been installed in JR companies' Shinkansen trains since 2017.



Large-scale Shaking Table with a Shinkansen Bogie

On October 23, 2004, the Mid Niigata Prefecture Earthquake occurred and the Shinkansen train Toki 325 became the first Shinkansen train running with passengers to derail. In response, RTRI, in cooperation with JR companies that operate Shinkansen trains, developed technologies to prevent the derailment or deviation of Shinkansen trains. RTRI's large-scale shaking table (*Large-scale Shaking Table with a Shinkansen Bogie*) and various simulation technologies contributed to the development of these technologies.

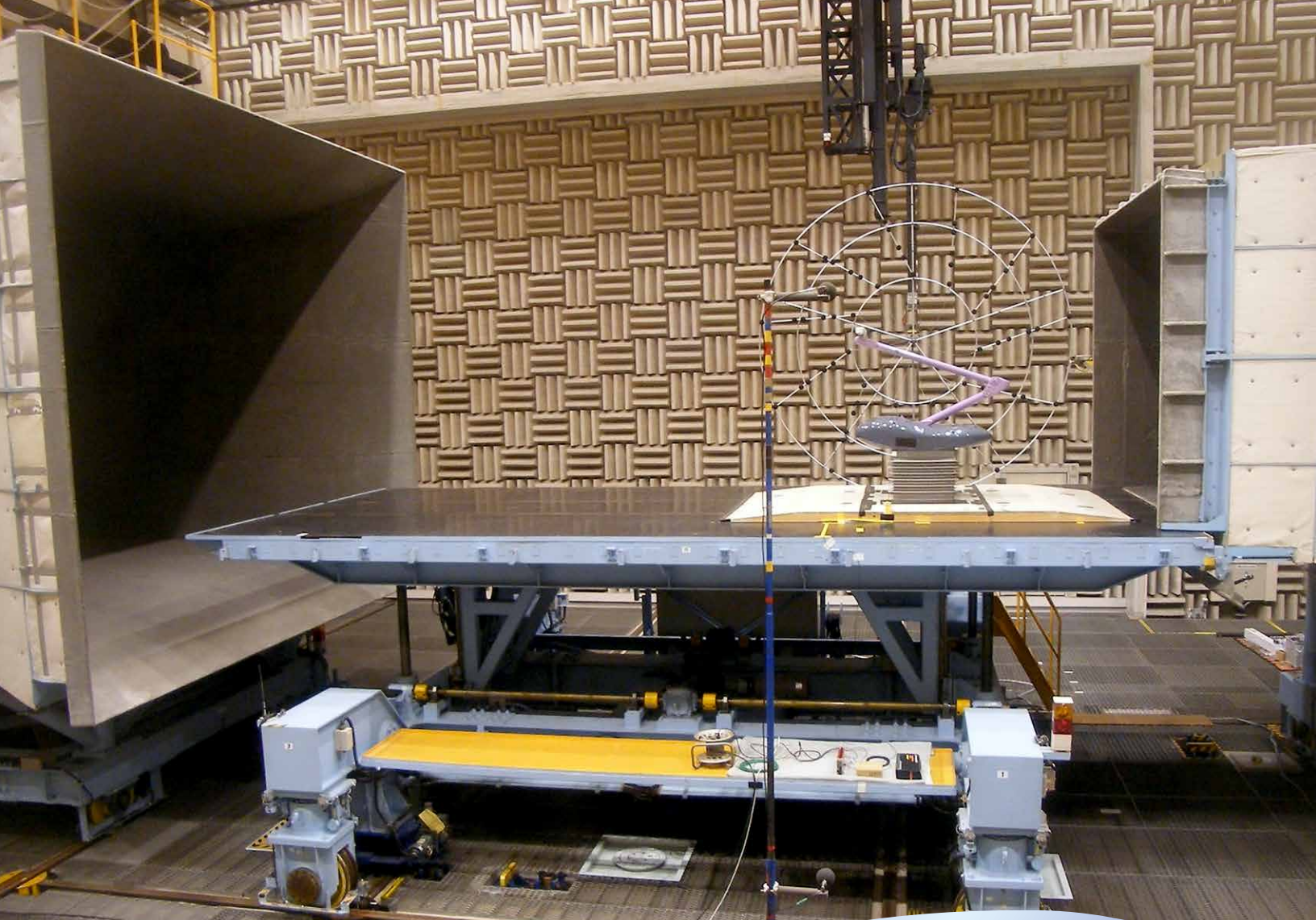
### Harmony with Trackside Environment —Resolution of various aerodynamic issues—

When the Shinkansen started operations, it had the problem of generating more noise than conventional lines because it runs at a higher speed.

To reduce noise, it is important to know (1) where the sound is coming from (sound source identification) and (2) how much the sound will be reduced by countermeasures (noise evaluation and prediction). So, RTRI developed a technology for identify-

ing the sound source using microphone arrays with microphones arranged in two dimensions, a large-scale low-noise wind tunnel facility (*Noise Measurements of Pantograph in Large-Scale Low-Noise Wind Tunnel*) for evaluating aerodynamic noises generated by each part of the train, and a technology for predicting trackside noises using the propagation characteristics of each sound source.

In addition, after the Sanyo Shinkansen was extended to Hakata (the terminal station in Kyusyu Island) in 1975, "micro-pressure waves" became a problem. This is



Noise Measurements of Pantograph in Large-Scale Low-Noise Wind Tunnel

a phenomenon in which a loud blast sound occurs at the exit of a tunnel when a train rushes into the tunnel. These micro-pressure waves are generated by the following mechanism: when the front of the train enters a tunnel at high speed, the air in front of the train is compressed, causing the pressure to rise, and this forms a compression wave that travels at almost the speed of sound through the tunnel, and when it reaches the exit, it is radiated externally as a pulse-shaped pressure wave. In response, RTRI proposed measures to mitigate the rate of change of pressure in the compres-

sion wave in the tunnel, specifically the installation of a tunnel entrance hood and improvements to the shape of the front of the train. As a result of these measures, the maximum operating speed was increased to 300 km/h in 1997 and to 320 km/h in 2013, and it remains at this level to the present day.

### Aiming for Further Evolution

The Shinkansen is characterized not only by its high speed, but also by its superior environmental performance compared to

cars and airplanes. In Europe, in particular, an ambitious plan is underway to actively utilize eco-friendly high-speed rail to realize a decarbonized society, and simultaneously, to double the number of passengers by 2030<sup>2)</sup>. Japan's Shinkansen trains will also evolve in the future to consume less energy than now and to reduce the environmental influence along their lines.

Anticipating further evolution of Shinkansen trains, RTRI constructed a low-noise moving model test facility (*Low-Noise Moving Model Test Facility*) that



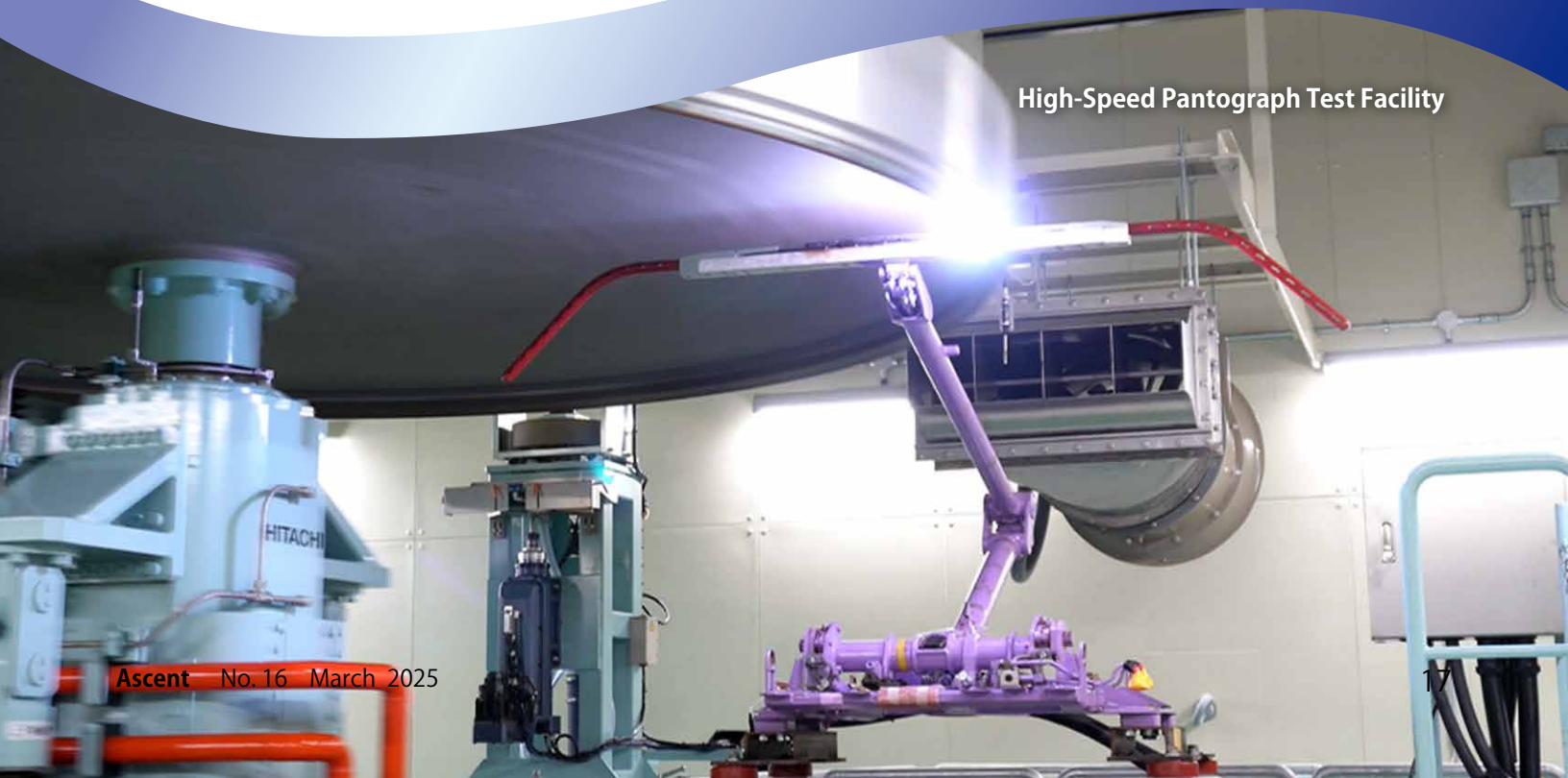
Low-Noise Moving Model Test Facility

can reproduce micro-pressure waves by plunging a 1/20-scale model train into a model tunnel at a maximum speed of 400 km/h, and a high-speed pantograph test facility (*High-Speed Pantograph Test Facility*) that can verify the current-collection performance of an actual pantograph by rotating a disk with a trolley line attached at a maximum speed of 500 km/h. These facilities were constructed for the Shinkansen trains based on the previous master plan, RESEARCH 2020. We will contribute to the further evolution of the Shinkansen by using these new test rigs, unique test facilities and unique analytical capabilities described in this report.

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## References

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High-Speed Pantograph Test Facility