

# RTRI Large-Scale Low-Noise Wind Tunnel



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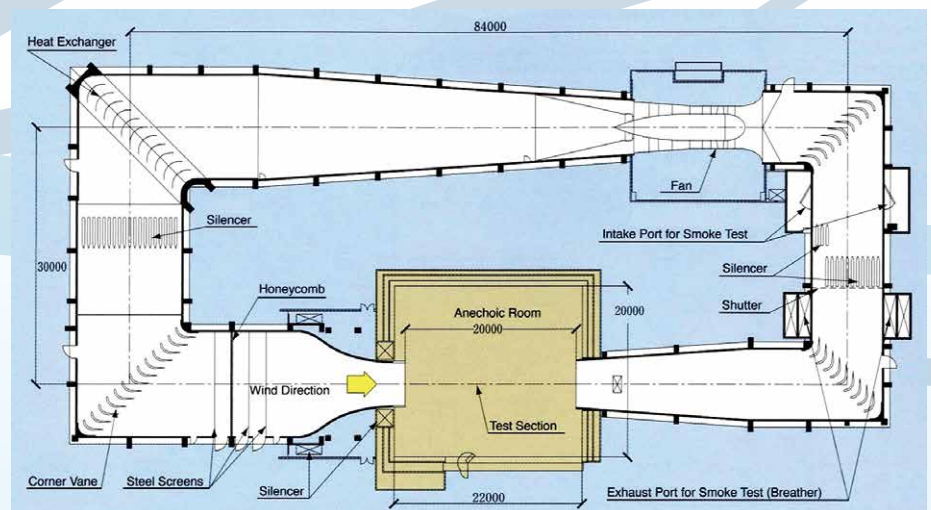
RTRI built a large-scale, low-noise wind tunnel (hereinafter “Maibara Wind Tunnel”) in Maibara City, Shiga Prefecture in 1996 for the R&D of railway aerodynamic issues, including aerodynamic noise. At the Maibara Wind Tunnel, we have contributed to various R&D activities related to aerodynamics by conducting more than 200 days of tests every year from opening the facility to the present. In particular, "safety" and "environment" are the most important issues in railways. Therefore, we have been actively researching and developing vehicle running safety in cross winds and aerodynamic noise reduction. This article overviews the characteristics of the Maibara Wind Tunnel built for the railways, a tunnel which has low background noise (noise generated by the wind tunnel during air blowing), a long test section, and to simulate air flow near the ground. It also summarizes the cross wind and aerodynamic noise-related R&D that utilizes the Maibara Wind Tunnel.

## Wind Tunnel Test Facilities

General arrangement shows a plan view of Maibara Wind Tunnel. Table summarizes its main specifications.

### Test Sections

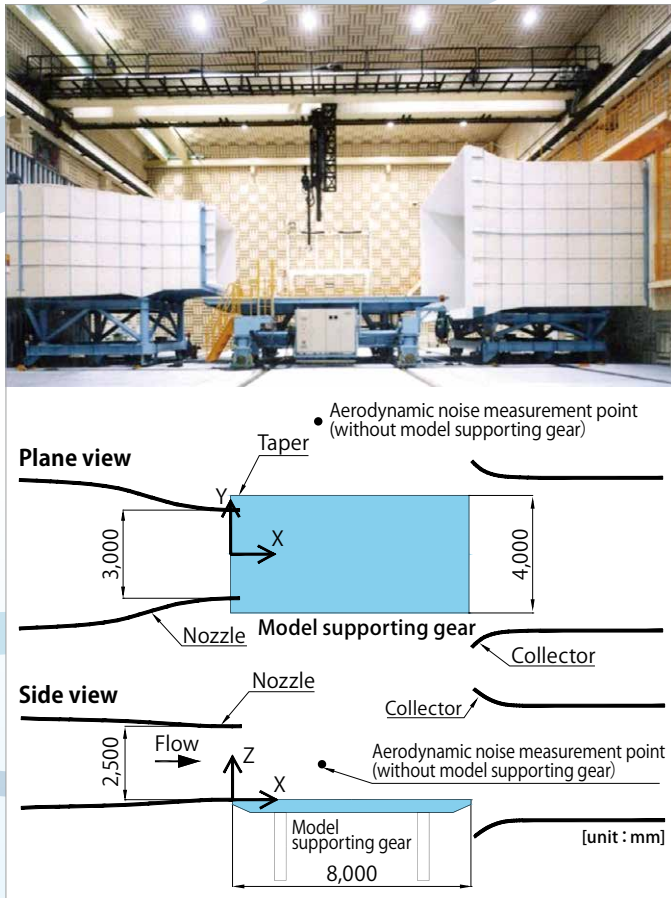
The Maibara Wind Tunnel has two types of test sections, open and closed, which are used depending on the purpose of each wind tunnel test. The open type test section has a width of 3 m, a height of 2.5 m, and a length of 8 m. This type of section allows testing of full-scale components (e.g., a pantograph). A maximum wind speed of 400 km/h (111 m/s) can be achieved,



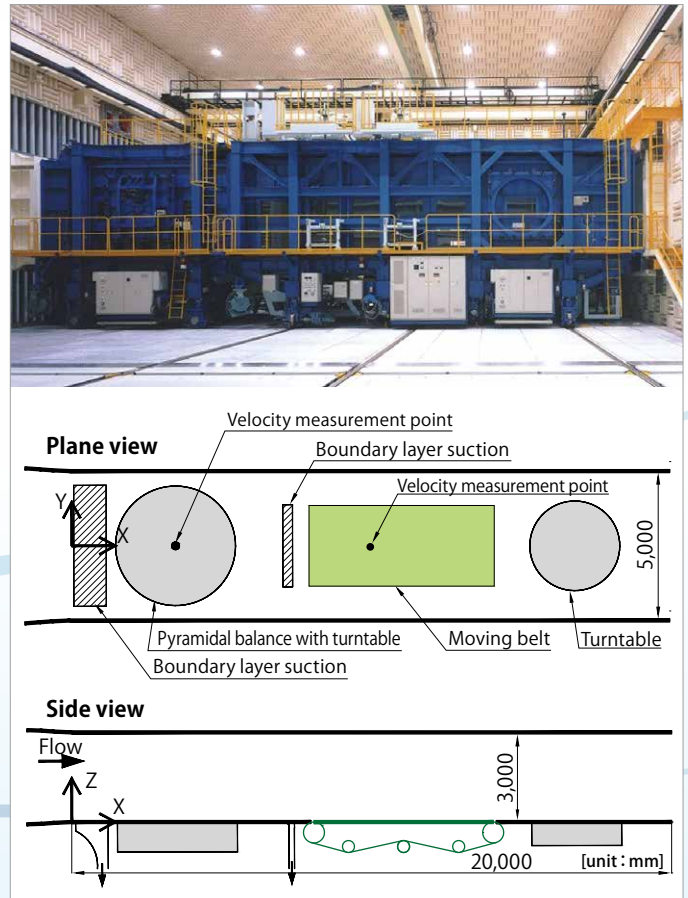
**General arrangement**

## Specifications

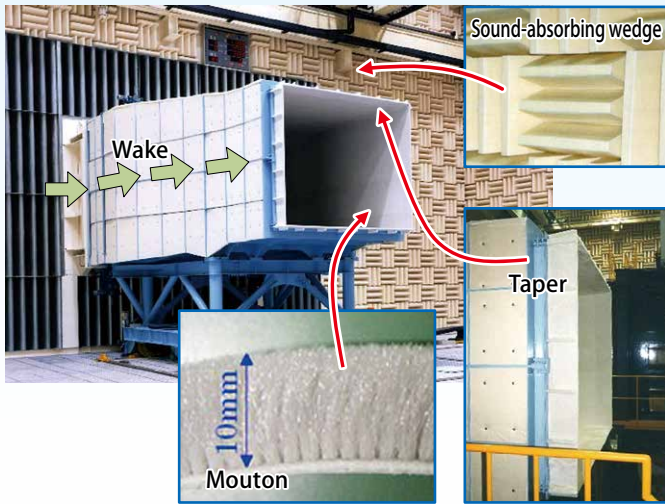
| Item                        | Specifications                                                                                                               |                                    |
|-----------------------------|------------------------------------------------------------------------------------------------------------------------------|------------------------------------|
| Wind tunnel type            | Göttingen-type single return wind tunnel                                                                                     |                                    |
| Test section type           | Open type                                                                                                                    | Closed type                        |
| Test section width & height | 3.0m(W) × 2.5m(H)                                                                                                            | 5.0m(W) × 3.0m(H)                  |
| Test section length         | 8.0m                                                                                                                         | 20.0m                              |
| Maximum wind velocity       | 400km/h (111m/s)                                                                                                             | 300km/h (83m/s)                    |
| Contraction ratio           | 16:1                                                                                                                         | 8:1                                |
| Uniformity of wind velocity | Under ±0.7%<br>at 324km/h (90m/s)                                                                                            | Under ±0.4%<br>at 288km/h (80m/s)  |
| Turbulence intensity        | Under 0.2%<br>at 360km/h (100m/s)                                                                                            | Under 0.2%<br>at 198km/h (55m/s)   |
| Background noise level      | 75.6 dB(A) at 300 km/h (83 m/s)                                                                                              |                                    |
| Measurement devices         | Sound level meter                                                                                                            | 6-component balance with turntable |
|                             | Beamforming wheel array microphone φ1m, φ4m                                                                                  | 6-component wire balance           |
|                             | Elliptical acoustic mirror φ1.3m                                                                                             | Pressure scanning system           |
|                             |                                                                                                                              | Built-in-type 6-component balance  |
| Main facilities             | Anechoic room<br>20m(W) × 22m(L) × 13m(H)                                                                                    | Moving belt<br>2m(W) × 6m(L)       |
|                             | Traversing gear                                                                                                              | 0-60m/s                            |
|                             | Supporting table with turntable                                                                                              | Boundary layer suction system      |
|                             | Flow visualizing system                                                                                                      |                                    |
| Dimensions                  | 94m Total length, 42m total width, 10m total height, 228m total path length                                                  |                                    |
| Fans                        | 5m in diameter, 12 moving blades, 17 stator blades, 590rpm maximum rotation, 7MW traction motor, Three phase induction motor |                                    |



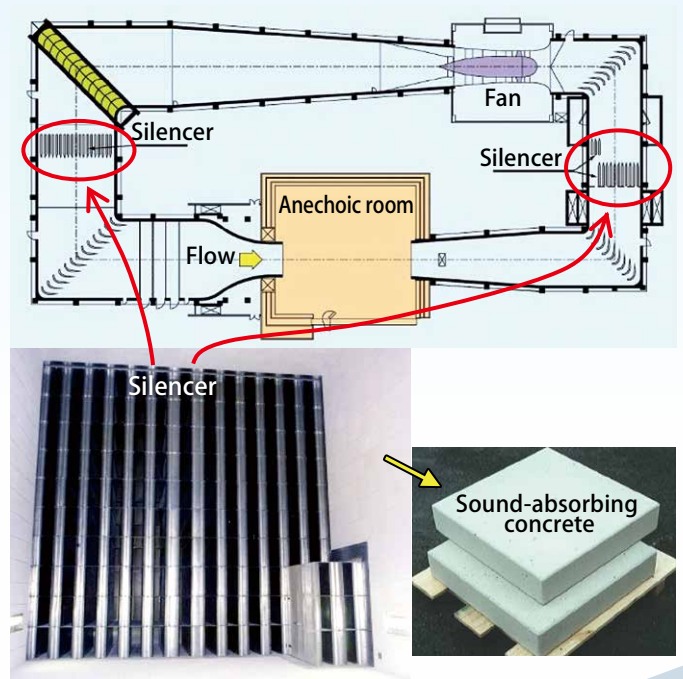
**Open type test section**



**Closed type test section**



**Noise reduction technology (Air duct)**



**Noise reduction technology (Anechoic room)**

which exceeds the operating speed of the Shinkansen, and is sufficient for R&D on the aerodynamic noise of the Shinkansen. The closed type test section has a width of 5 m, a height of 3 m, and a length of 20 m. This test section is very long compared to its height, which allows scale-model train sets to be tested. In addition, this type can be used for tests that reproduce the boundary layer of natural wind. The maximum wind speed in the closed type is 300 km/h (83 m/s).

**Noise reduction technologies**

Before the construction of the Maibara Wind Tunnel, most of the available wind tunnels generated large background noise. Therefore, their signal-to-noise ratios were low, making it difficult to conduct aerodynamic noise tests. The Maibara Wind Tunnel has various technologies for reducing noise and makes it possible to conduct aerodynamic noise tests by keeping background noise low.

**1) Noise reduction technology in the air duct**

- Silencers are installed on the internal cross-sections of the

air duct on the upstream and downstream sides of the fan to prevent the noise of the fan from affecting the test section.

- The inner wall of the air duct is covered with sound-absorbing concrete to reduce the noise in the air duct.

**2) Noise reduction technology in the test sections**

- The entire wall surface, including the bottom surface, of the test section is covered with sound-absorbing wedges to prevent the noise generated by the test model or wind tunnel from being reflected from the walls.
- The jet noise from the nozzle is reduced by reducing the speed difference between the main flow and peripheral flow. For this

purpose, the boundary layer was thickened by attaching mouton to the inner surface of the nozzle and slightly widening the nozzle tip. In addition, wake has been produced with outside air taken in to the outer shell of the nozzle.

By adopting these noise reduction technologies, the wind tunnel has achieved low noise performance with a background noise level of 75.6 dB (A) at a wind speed of 300 km/h.

**Simulation of ground flow**

To simulate the flow between a running vehicle and the ground in a wind tunnel test, we need to eliminate the boundary layer that develops on the floor of the wind tunnel. In the Maibara Wind Tunnel, boundary layer suction devices clear the boundary layer on the floor by sucking it in, and a moving belt suppresses the development of the boundary layer by moving at the same speed as the main flow .

## R&D Activities

### Research on vehicle running safety against cross winds

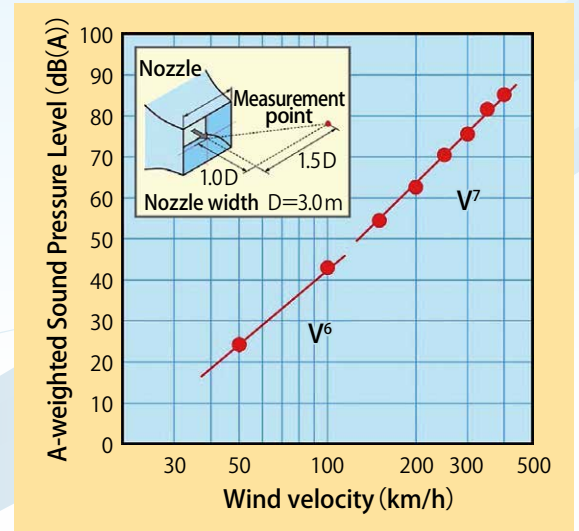
Initially, we conducted wind tunnel tests of the aerodynamic force acting on the vehicle by cross winds by installing only a vehicle within a uniform flow. However, we now know that the aerodynamic force on the vehicle is affected not only by the shape of the vehicle but also by the shape of the ground structures and the wind velocity distribution and turbulence intensity. Thus, we are conducting tests where the ground structures are reproduced in the wind tunnel test section and natural wind is simulated. So far, we have evaluated the coefficients of aerodynamic force by combining five typical vehicle shapes and seven ground structures. We have also evaluated the aerodynamic force of the ground structures that are significantly different in shape from these seven types (e.g., half-bank half-cut structure) and evaluated the effects of windbreak fences. Furthermore, to deepen research on the aerodynamic force acting on the vehicle due to cross winds, we are conducting research on the effect of vehicle running on aerodynamic

force and the effect of cross winds on vehicle dynamics in a wind tunnel test of a vehicle model that reproduces the vehicle's suspension system. In addition, the Maibara Wind Tunnel is used extensively in studies on hardware measures such as the installation of windbreak fences, which is one of the effective measures against cross winds (e.g., prechecking the effect by wind tunnel tests).

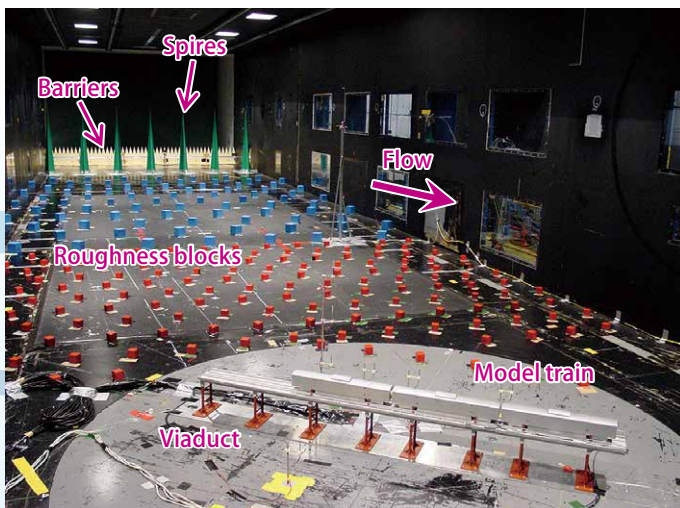
### Research on aerodynamic noise

The R&D to reduce aerodynamic noise for the speeding up of the Shinkansen was the primary purpose of the construction of Maibara Wind Tunnel. So far, we have conducted aerodynamic noise reduction R&D for current collection equipment including pantographs and insulators, which has greatly contributed to the speeding up of the Shinkansen. The aerodynamic noise from pantographs is known to be greatly influenced by

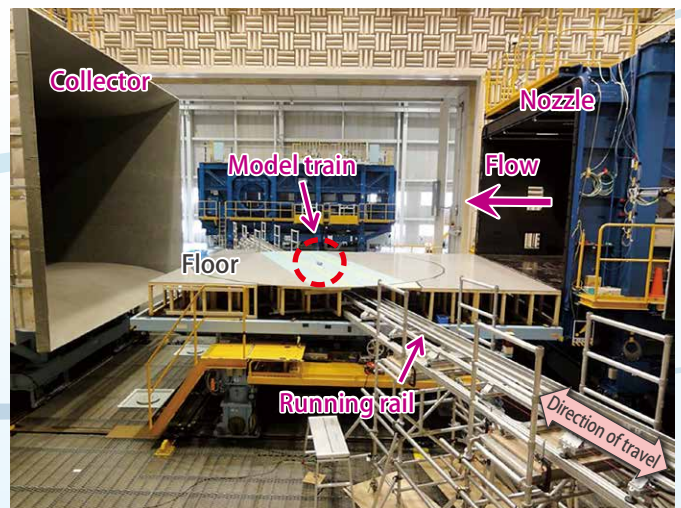
the pantograph head. However, the aerodynamic lift acting on the pantograph head during high-speed running must be stable. Thus, focusing on the cross-sectional shape of the pantograph head and the positional relationship between the pantograph head and its support, we are proceeding with R&D on pantographs that achieve both the reduction of aerodynamic noise and the stabilization of aerodynamic lift characteristics.



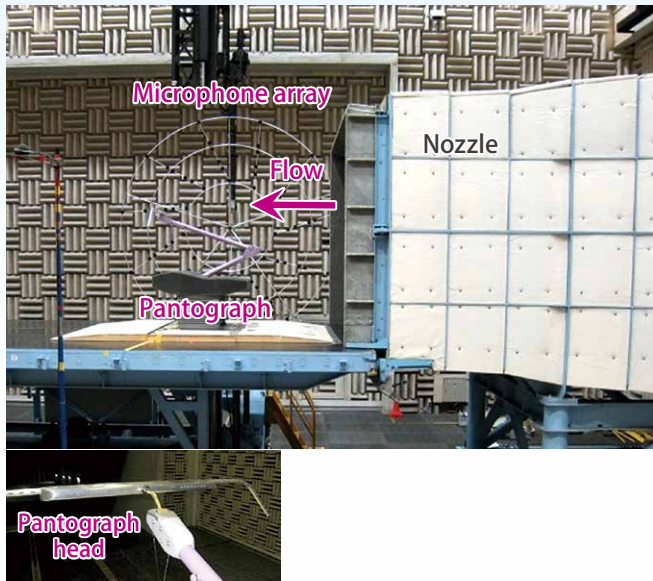
Measured background noise



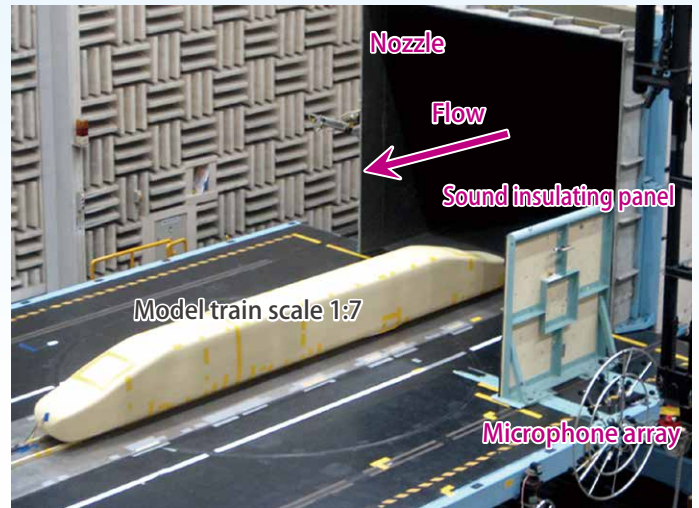
Wind tunnel tests for the train model on the viaduct under crosswind



Moving model rig



Measurement of aerodynamic noise from pantograph



Measurement of aerodynamic noise from bogie-section

Meanwhile, the R&D up to now has reduced the aerodynamic noise of the current collection equipment, and we predicted the wayside noise from Shinkansen using field test results. As a result, we clarified that the vehicle's bogie section is one of the main sources of aerodynamic noise in addition to the current collection equipment. Our wind tunnel test of the noise of the bogie-section at the Maibara Wind Tunnel has shown that this noise is effectively reduced by suppressing air flow into the bogie section using deflectors installed before and after the cavity of the bogie section.

### Conclusion

The large-scale, low-noise Maibara Wind Tunnel has contributed to R&D on railway vehicles conducted by RTRI and JR companies for 25 years since its completion. In 2016, the renewal work of the motor (the "heart" of the wind tunnel), which drives the fan, and the inverter,

which supplies electricity to the motor, was completed successfully. We would like to continue to contribute to the R&D of aerodynamic issues of railways by taking advantage of the world's top-class wind tunnel.

Replacement of motor

