inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 0.0

DEVELOPMENT AND PROSPECT FOR LOW NOISE PANTOGRAPHS

T. Okamura, Y. Kusumi, T. Hariyama

JR EAST, 2-2-2 Yoyogi Shibuya-ku, 151-8578, Tokyo, Japan

Tel.: +81 3 5334 1146 / Fax: +81 3 5334 1108 / Email: t-okamura@head.jreast.co.jp

Keywords:
AERODYNAMIC NOISE, PANTOGRAPH, INSULATOR

ABSTRACT
Shinkansen trains run mainly on elevated railways and the noise caused by their running consists of trolley-pantograph noise, body aerodynamic noise, wheel/rail noise, and structure-borne noise. Among these, wheel/rail noise has the biggest energy, but it has been cut off effectively by soundproof walls all along the line. Therefore, for the Shinkansen, reduction of trolley-pantograph noise has been the main problem for the speed-up. We have restrained the aerodynamic noise by installing pantograph covers on the train roof until now. However, since pantograph covers themselves generate aerodynamic noise, we have developed a "new low-noise pantograph" without pantograph covers. This paper introduces the development of the low noise pantograph and insulator, focusing on results of wind tunnel tests.

1 - INTRODUCTION

Japanese high-speed Shinkansen trains run mainly on elevated railways and the wayside noise caused by their running consists of trolley-pantograph noise, body aerodynamic noise, wheel/rail noise, and structure-borne noise.
For wayside noise from the Shinkansen, the environmental standards below are established in the basic law for antipollution measures.

1. Standards for Wayside Noise
   - for living areas
   - for other areas that need to be protected for general life
2. Measuring and Estimating Methods for Wayside Noise
   - for 20 consecutive trains (both up and down) in principle, the peak levels of noise are measured.
   - the wayside noise is estimated by averaging the power levels of the noise for the upper half of these 20.
   - Measuring point should be a representative of the area, and measuring height is 1.2 m from the ground level in principle.

Based on this, we measure the wayside noise with the method shown in Fig. 1.
Among the noise caused by the running of the train, wheel/rail noise has the biggest energy, but it has been cut off effectively by soundproof walls all along the line. Therefore, for the Shinkansen, reduction of trolley-pantograph noise has been the main problem. Trolley-pantograph noise, especially the aerodynamic noise of the pantograph, is proportional to the sixth power of the train speed, so it requires a special abatement technique for the speed-up of Shinkansen trains.
So far we have restrained the aerodynamic noise by installing pantograph covers on the train roof to decrease the velocity of air around the pantograph, mainly around the collector shoe.
However, when smaller cars were used to reduce aerodynamic noise, pantograph covers became larger and generated more aerodynamic noise. Thus, a low-noise single-armed pantograph (type PS206) has been developed to abate the noise emission from pantographs.

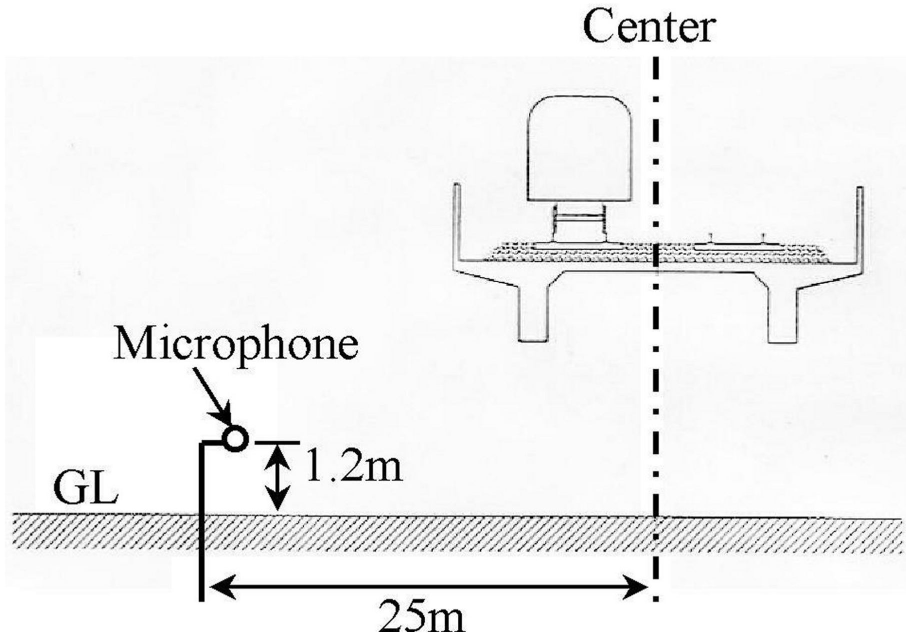

Figure 1: Measurement of wayside noise.

This type was installed on series E3 cars with small pantograph covers (Fig. 2), and contributed to 275 km/h commercial operation speed.
To reduce the trolley-pantograph noise further, it is necessary to do without pantograph covers. Therefore, we studied the noise reduction of support insulators for pantographs, and developed a low-noise insulator. Also, we started the development of a new low noise pantograph to reduce the noise of the pantograph itself [1], [2].
Fig. 3 shows the comparison between present shape (used with pantograph cover) and newly developed shape for insulators.
The mechanism of the aerodynamic noise emission from insulators is understood as Fig. 4 shows. The train wind is accelerated in the narrow spaces between the ribs of the insulators, causing a velocity difference from the flow outside. Thus, a strong disturbance is created behind the insulator. That disturbance is considered a noise source.
To reduce this disturbance, it was suggested to lengthen the diameter of the insulator in the flow direction. The turbulence boundary layer was expected to develop before the flow reaches the wake area of the insulator, reducing the velocity of the accelerated flow.
The new low-noise pantograph is based on the current low-noise single-armed pantograph (type PS206). It was requested to have aerodynamic performance equivalent to PS206, independent of the running direction. Based on these requirements, we carried out scale-model wind tunnel tests, full-scale-model wind tunnel tests, and train tests with the pantograph in use. Thus we confirmed its performance, which is described below.

2 - RESULTS OF THE WIND TUNNEL TESTS

2.1 - 1/10 model wind tunnel tests

The pantograph base frame, now covered by the pantograph cover, will be exposed to flow without the pantograph cover. So the shape of the base frame must be improved. The base frame is equipped with the mechanism to fold/unfold the pantograph. It is covered with a fairing, mainly to reduce the noise and protect from snow. The shape of the base frame was investigated for reducing the aerodynamic noise in our research. The 1/10 model wind tunnel tests showed that thin base frames with smooth connection with the insulators gave less noise (Fig. 5).
Next the selected base frames with the supporting frame were tested. Single-arm pantographs give different noise level with different direction to the flow, due to their asymmetric supporting frames. Let us say that the pantograph is in the "leading direction" when the elbow of its supporting frame is directed upwind, or to the front of the train, while we would say "trailing direction" when the elbow is direction downwind (Fig. 6). As a result, the new pantograph generated more noise in the leading direction (Fig.

Figure 2: PS206 + insulator cover (series E3).

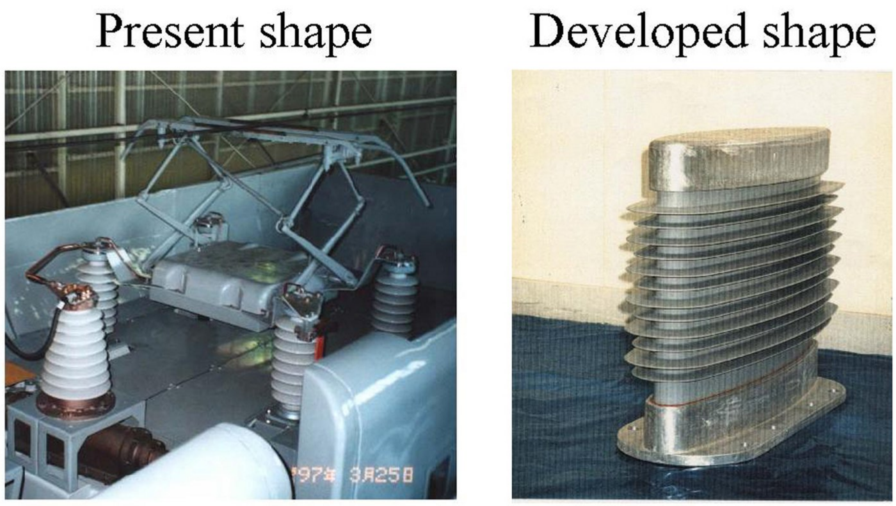

Figure 3: Comparison between insulators.

7). The phenomenon was found to be cause of the interference with the supporting frame and the cavity on the base frame.

2.2 - 1/5 model wind tunnel tests

As for the pantograph base frame, an asymmetric shape having different thickness at both ends was developed, with consideration for the mechanism in it. The connection with the insulators was smoothed as if they were a single component. Combined with the single-arm supporting frame, the interference noise was abated, resulting in significant noise reduction compared with PS206 plus low noise insulators in the leading direction (Fig. 8).

As for the collector shoe, we developed several candidates whose lower surface had intentionally regular roughness based on PS206 (Fig. 9).

This was intended to shorten the correlation length of vortices emitted from the collector shoe, which had a rectangular cross-section, as well as to make the phases of those vortices different from one another. Thus the energy of the vortices was expected to reduce. The results of the wind tunnel tests for them are shown in Fig. 10. The optimal collector shoe reduced the noise by 1 dB(A) at overall value.

2.3 - Full-scale model wind tunnel tests

Next, full-scale model wind tunnel tests were carried out to confirm the noise level and aerodynamic characteristics.

This wind tunnel belongs to RTRI (Railway Technical Research Institute). Table 1 shows its specifications. The structure is shown in Fig. 11 and a scene of tests in Fig. 12.

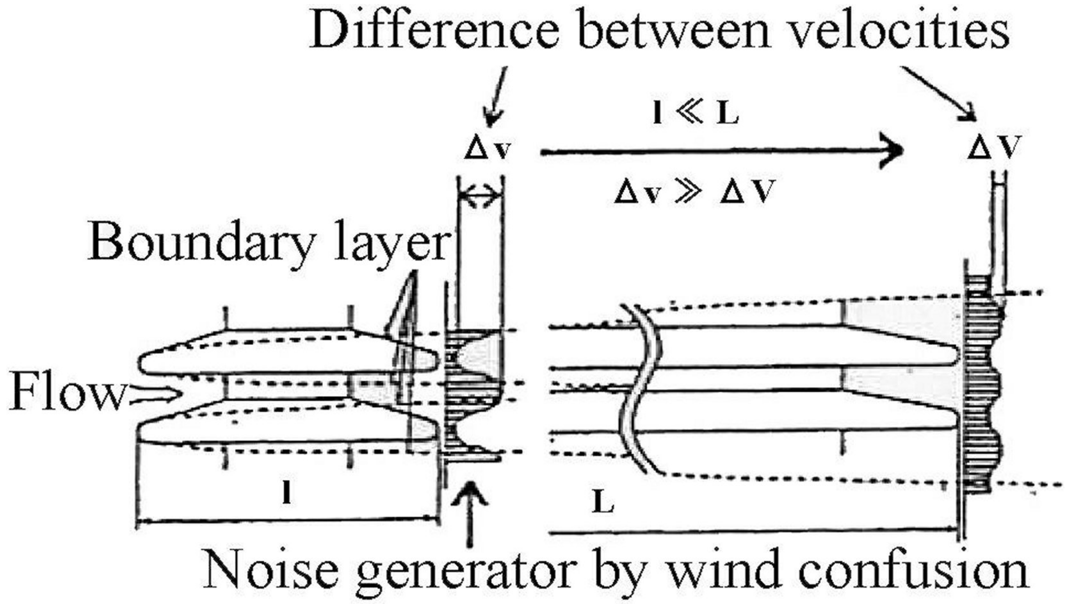

Figure 4: Mechanism of aerodynamic noise of insulator.

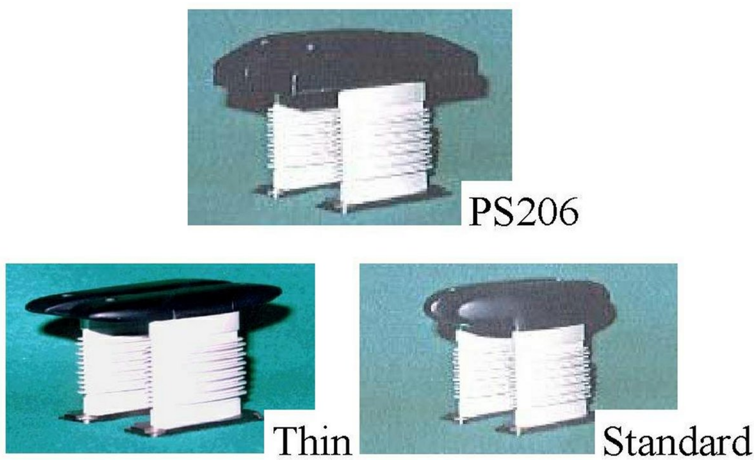

Figure 5: 1/10 models.

ITEM	SPECIFICATION
Width & Height	3000 ×2500 [mm]
Length	8000 [mm]
Maximum Wind Velocity	400 [km/h]

Table 1: RTRI's large-scale low-noise wind tunnel.

For the tests, the pantograph base shape and the collector shoe selected in the 1/5 test were adopted here. For the mechanism to support the collector shoe, a new one was adopted to reduce noise.
The Ideally Shaped Pantograph (I.S.P.), having all the components thus developed, with the low-noise insulators (Fig. 13), achieved 2 dB(A) at overall value noise reduction compared with PS206 (collector shoe and supporting frame only) (Fig. 14). The pantograph base frame did not generate the correlation noise, similar to the 1/5 model experiments. There was no difference between the leading direction and the trailing direction. The improvements of the shoe support shape reduce the noise in comparison with PS206.

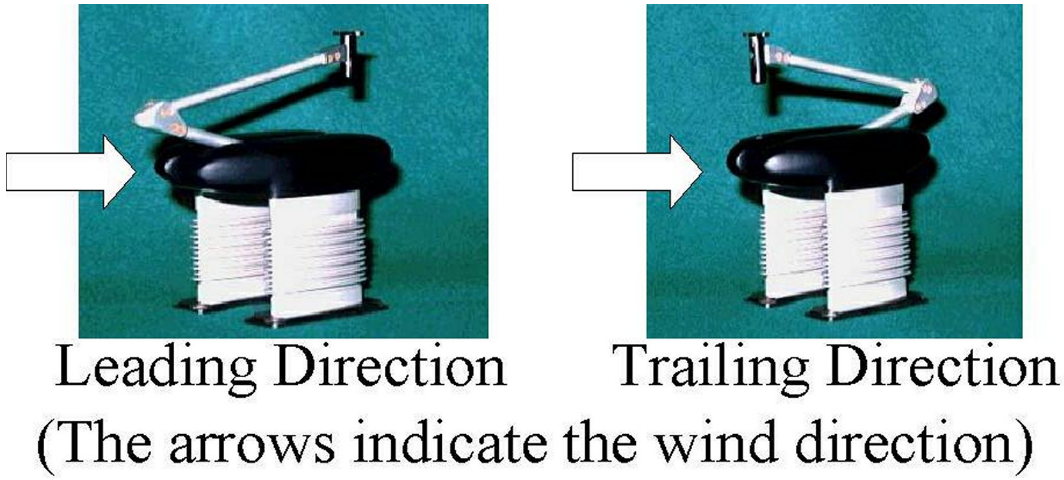

Figure 6: Direction of pantograph.

3 - FULL-SCALE TRAIN TESTS USING SERIES E2 CARS

3.1 - Verification of the train-test pantograph

Next, a developed pantograph and insulator would be installed on existing cars (series E2) to verify the effect for noise reduction. But there were two main problems about installing them on present cars with original shapes. One is that the roof of the present cars is too high to install the pantograph within the vehicle gauge limit for pantographs folded. The other is that an Emergency Switch must be added for running. Then a Train-Test Pantograph based on the Ideally Shaped Pantograph was adjusted to be installed on present cars for train tests. We compared the noise of the two kinds of pantographs by the wind tunnel test, before train tests were carried out. Fig. 15 shows the Train-Test Pantograph as adjusted. As Fig. 16 shows, in the wind tunnel the Train-Test Pantograph was more noisy by 3 dB(A) at overall value than the Ideally Shaped Pantograph.

3.2 - Results of the train tests

The Train-Test Pantograph was installed on a series E2 car with the low-noise insulators which conduct air and electricity (Fig. 17). As for the power collecting performance, there was no problem up to 315 km/h. The wayside noise in a high-speed (315 km/h) test was equivalent to that of existing pantographs with pantograph covers (present series E2). Thus, if the Ideally Shaped Pantograph (coverless) is used, the wayside noise is expected to reduce.

4 - FUTURE DEVELOPMENT

Our new low-noise pantographs with low-noise insulators were found to generate less noise than existing pantographs with covers, if the "ideal" shape (coverless) is feasible.

Now we are manufacturing new commercial cars that can be equipped with the Ideally Shaped Pantographs without adjustment. During this year, we will estimate the effect of noise reduction by new pantographs and insulators under actual use.

REFERENCES

1. **S.Nakagawa**, Low-noise pantographs and insulators, In *WCRR'97*, 1997

2. **T.Hariyama, et al.**, Low-noise pantographs and insulators (Vol.2), In *WCRR'99*, 1999

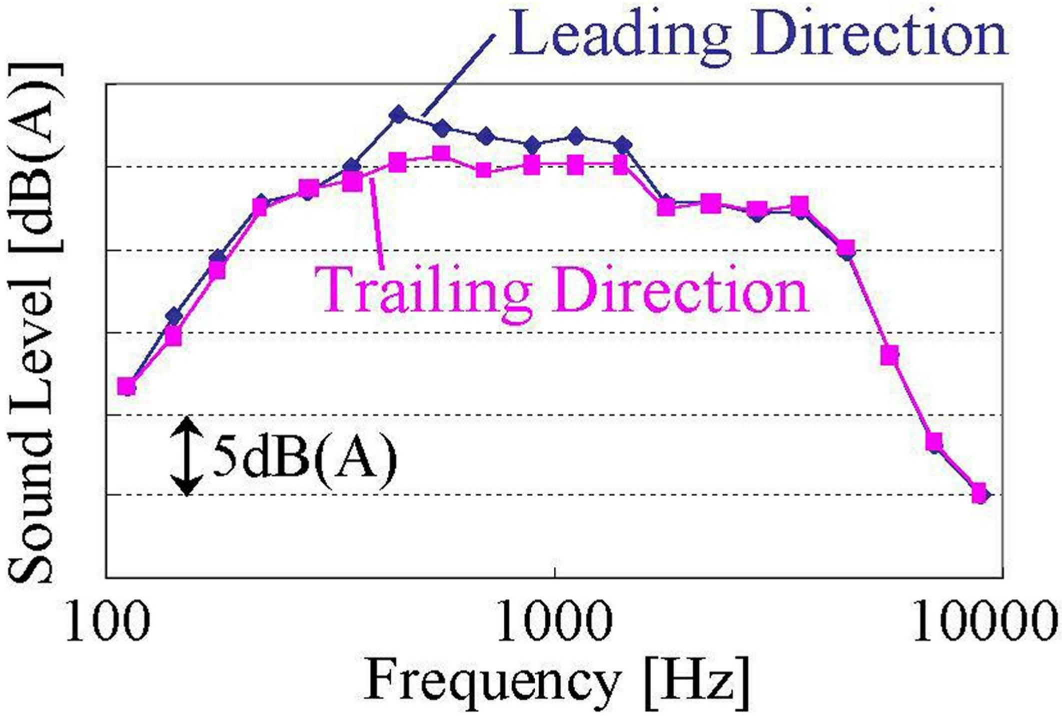

Figure 7: 1/10 model noise spectra.

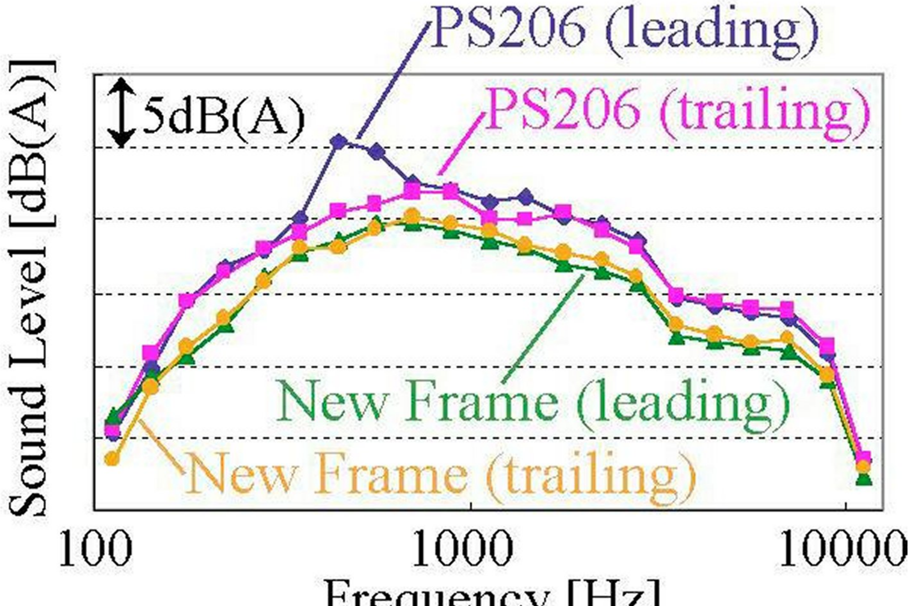

Figure 8: 1/5 model noise spectra.

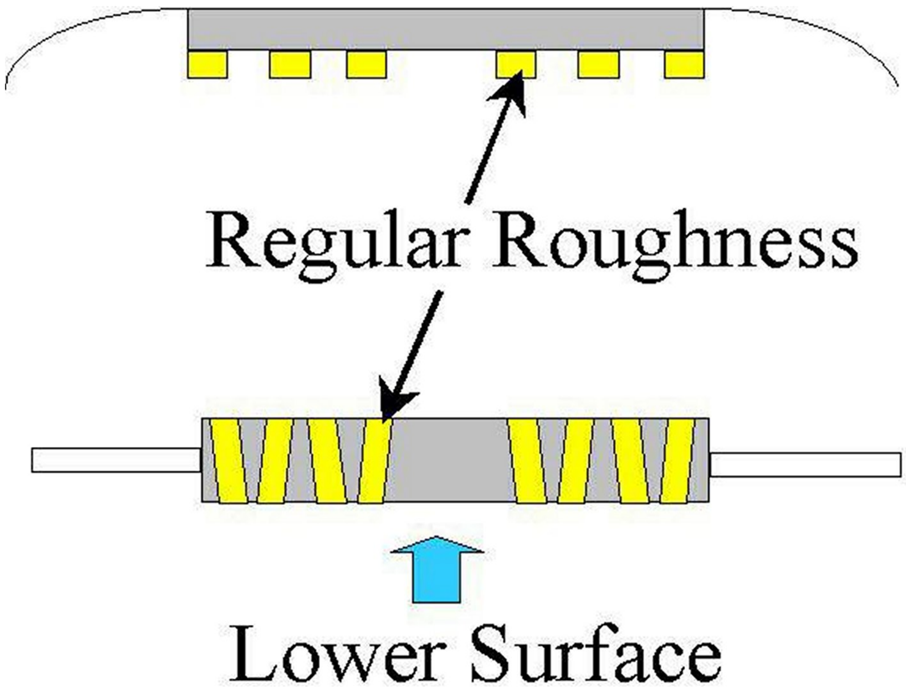

Figure 9: Developed collector shoe.

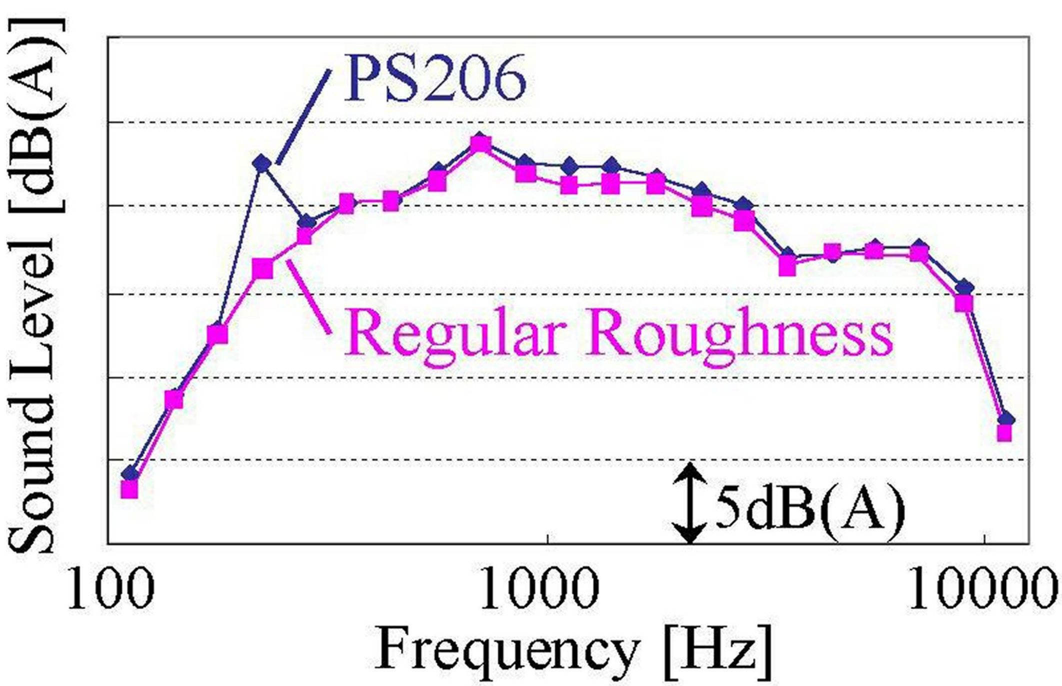

Figure 10: 1/5 model noise spectra leading direction.

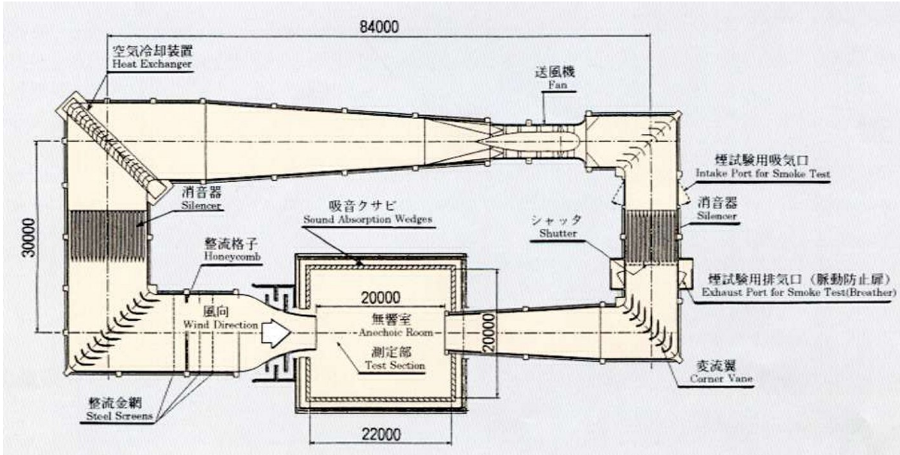

Figure 11: RTRI's large-scale low-noise wind tunnel.

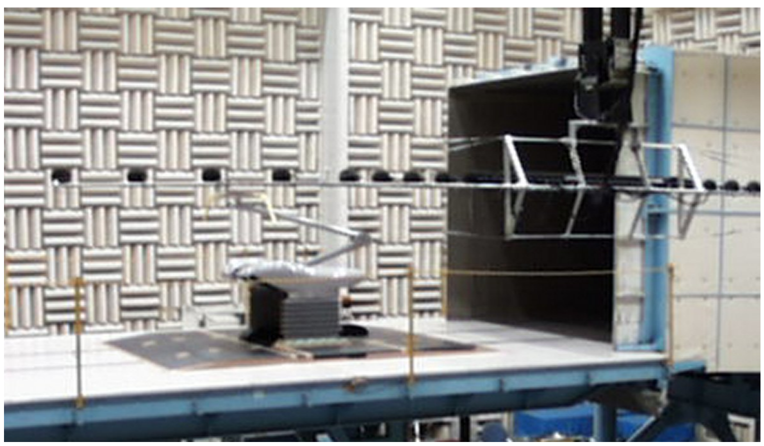

Figure 12: Scene of the large-scale wind tunnel tests.

Figure 13: Ideally shaped pantograph (I.S.P.).

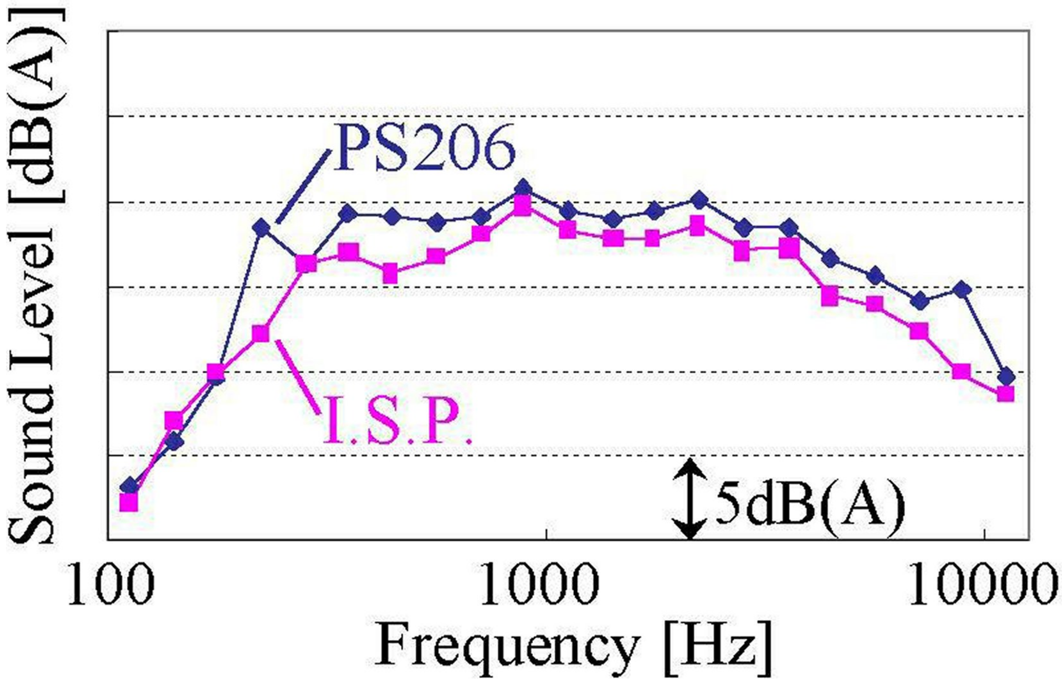

Figure 14: 1/1 model noise spectra leading direction.

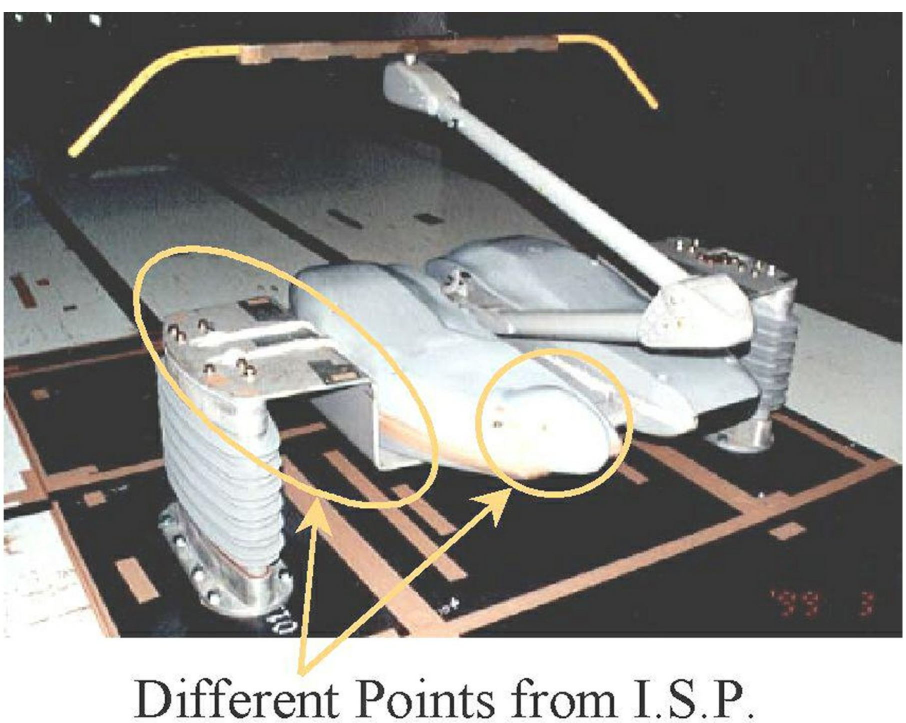

Figure 15: Train-test pantograph.

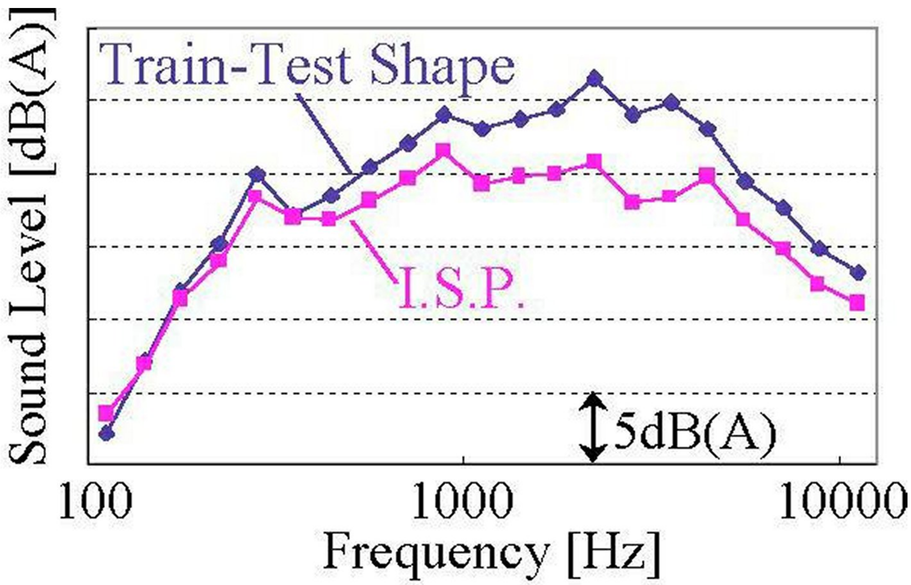

Figure 16: Model noise spectra leading direction.

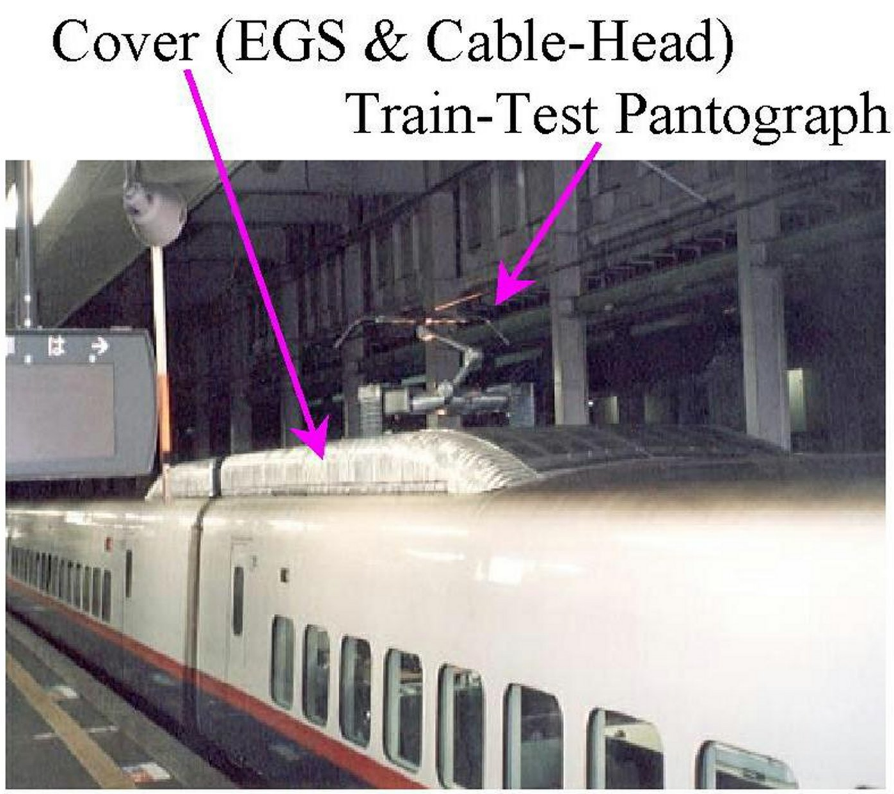

Figure 17: Train-tests (series E2).