Snow Accretion Removal Device for Vehicle Detectors of ETC Systems

NAGASHIMA, Jun* HISAMA, Hirotomo* TAKAHIRA, Isao ⁑

An ETC vehicle detector is one of the roadside devices that compose an ETC tollgate. It is the main device responsible for detecting the passage of vehicles. Fuji Electric has been providing a large number of vehicle detectors since the dawn of ETC systems. As of 2019, we have approximately 40% of the Japanese market share.

Due to recent work style reform and labor shortages, expressway companies are taking measures to make tollgates unmanned. Under these circumstances, there is a need to reduce the maintenance of ETC vehicle detectors as well. However, in areas affected by snowfall, there are some obstacles caused by adhesion of snow and ice, and this has been a major issue that has hindered labor savings. To solve this problem, we have developed a snow accretion removal device for ETC vehicle detectors in collaboration with NEXCO East Nippon Engineering Co., Ltd., a group company of East Nippon Expressway Company Limited.

1. Challenges for Vehicle Detectors in Snowfall Areas

Figure 1 shows the configuration of an ETC lane. The vehicle detector is a transmissive sensor consisting of multiple infrared light emitters and receivers. Light-emitting and light-receiving devices are installed on the left and right sides of the vehicle entry direction to detect the passage of vehicles in each detection area. Since the device is installed outdoors, rainwater, mud splashed by passing vehicles, and even ice and snow in snowy areas often adhere to the optical window. Normally, in order to prevent erroneous detection of vehicle passage due to such decreases in light-receiving power caused by foreign objects adhering to the optical window, a disconnection process is used via software to exclude the area with decreased light-receiving power from the detection functionality. However, in the event of a snowstorm, the temperature of the casing will drop and snow and ice will adhere to the entire optical window, making it impossible for the software to handle such a situation. When vehicle detection is not possible, ETC toll collection cannot be processed, leading to lane closure.

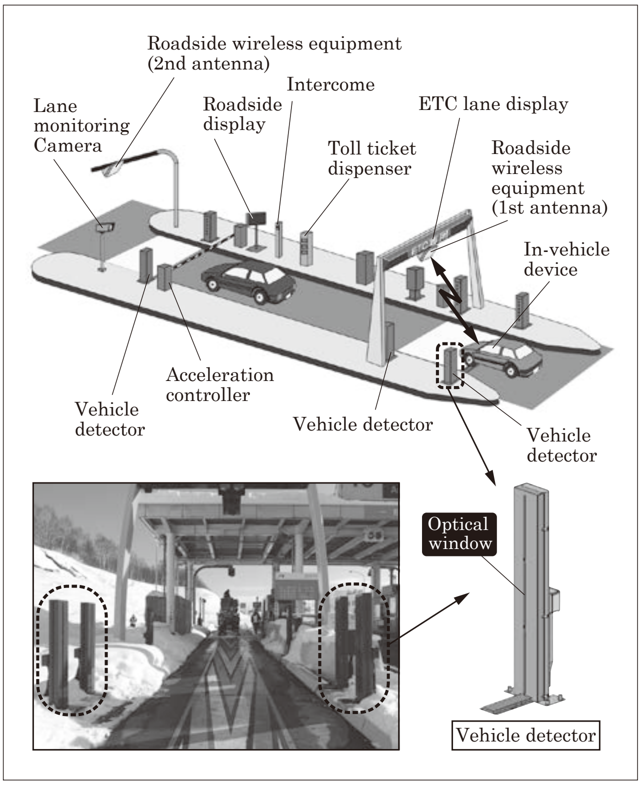


Fig.1 ETC vehicle detector lane configuration and vehicle detector

Even when using the cold-weather vehicle detectors that are in our product line-up, in severe weather conditions such as heavy snowstorms, the heaters in the sensors may not be able to melt the snow in time. In addition, there are events in which snow accumulates in an igloo-shaped manner that covers the foot heaters that were installed at the bottom of the detectors to prevent snow accumulation. As a result, this snow ends up obstructing the light path. As a countermeasure, we could simply increase the heater capacity, but this would increase power consumption and put a strain on the power supply from the customer's substation. It is against this background that there has been demand for "energy-saving and snow-resistant" vehicle detectors that can achieve labor savings at remote tollgates and smart interchanges.

* Power Electronics Systems Industry Business Group, Fuji Electric Co., Ltd.
⁑ Sales Group, Fuji Electric Co., Ltd.

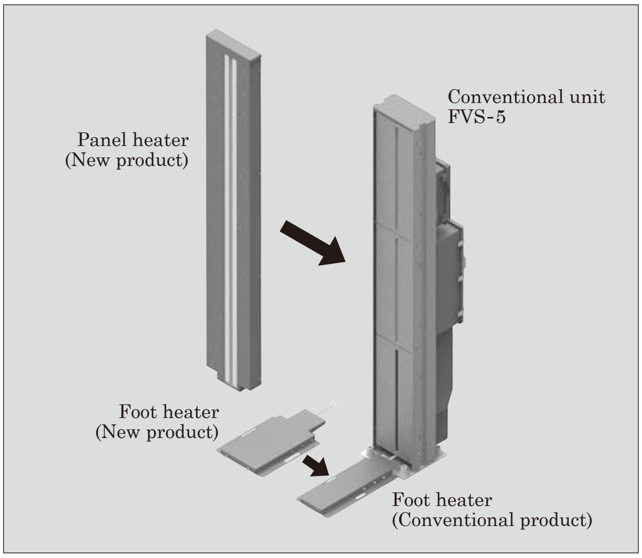


Fig.2 Equipment configuration of snow accretion removal device

Table 1 Specifications of snow accretion removal device

Item	Specification
Panel heater power	160 VA
Environmental specifications	−30°C to +50°C
Foot heater length	400 mm (standard)
Foot heater width	200 mm
Foot heater power (watt density)	120 VA (0.16 W/cm^2)

2. Specifications and Features of the Snow Accretion Removal Device

2.1 Specifications and features

Figure 2 shows the equipment configuration of the snow accretion removal device, and Table 1 shows the specifications of the snow accretion removal device.

The snow accretion removal device consists of a panel heater built on large, flat, heat-resistant tempered glass that covers the front of the sensor and a foot heater with a larger area than conventional products. Due to its modular structure, it can be retrofitted to existing “FVS-5 Series” vehicle detectors.

2.2 Field test results

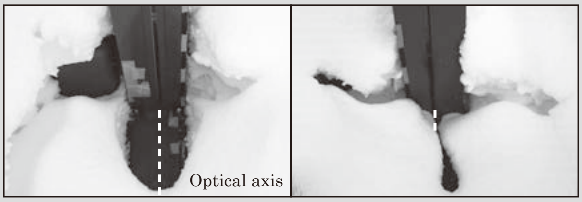
We performed a field test to compare the snow removal ability with that of a conventional product. Figure 3 shows the optical window and Fig. 4 shows the foot heater.

As shown in Fig. 3, the panel heater of the device is flat, making it difficult for snow to adhere to it, and even if it does adhere to it, the melting snow and ice easily slide off.

As shown in Fig. 4, the heating area of the foot heater has been expanded while minimizing the increase in power consumption. This helps prevent

(a) Snow accretion removal device	(b) Conventional product
No accumulation of snow on the surface (optical window).	The surface is covered with snow and ice in a way that obstructs the optical axis.

Fig.3 Field test (optical window)



(a) Snow accretion removal device	(b) Conventional product
Sufficient space is provided for light transmission.	The snow accumulates in an igloo-shaped manner that covers the top of the foot heater, blocking the transmission of light.

Fig.4 Field test (foot heater)

igloo-shaped snow accumulation. For details, see Section 3.1.

During the test period, the vehicle detectors equipped with the snow accretion removal device did not show any snow accumulation at a level that would affect the detection function. In particular, we confirmed that the system could operate without snow shoveling for about a week even when it was unmanned. In addition to improving the snow removal performance of both the panel heater and foot heater, we reduced the device’s power consumption by approximately 40% compared to conventional products by enhancing its heating control, heat distribution, and insulation structure.

3. Background Technologies

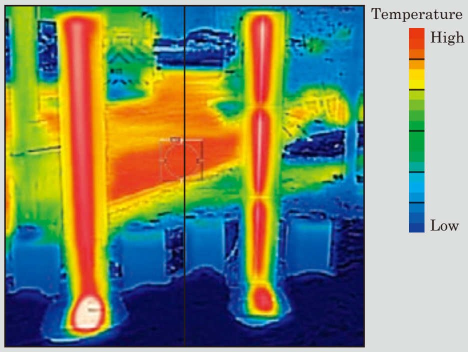
3.1 Temperature analysis technology

We made full use of thermal simulation technology when researching the structure of the panel heater of the snow accretion removal device. We parameterized conditions such as the joining method of each element constituting the panel heater, the thickness of the components, and the heater arrangement, and conducted dozens of pattern simulations to determine the optimal structure. Similarly for the heater capacity, by parameterizing the temperature and wind speed of existing tollgates, we determined the minimum heater capacity that can reach the target specification (temperature rise value $\Delta T = 40°C$).

We conducted the same analysis for the foot heater and devised an arrangement for the heating elements inside to prevent igloo-shaped snow accumulation. This enabled us to increase the heating area without increasing the power consumption, thereby improving the snow prevention performance.

3.2 Temperature control technology

By measuring the temperature of the large panel with thermocouples and performing feedback control for the heater, we were able to equalize the temperature distribution and suppress the thermal stress on the glass (see Fig. 5). By devising the arrangement and fixing method of the heater, we designed a structure that selectively heats the panel. At the same time, we improved heat retention by installing heat insulating material on the back of the device, and enabled it to achieve significant power savings (40% reduction) compared to conventional products. Furthermore, since the temperature at which snow falls differs in mountainous and plain areas, the heater temperature can be appropriately set and operated according to the characteristics of each region.



(a) Snow accretion removal device	(b) Conventional product
It can be confirmed that the optical window is uniformly warm.	Heating is uneven, and there are low temperature areas between each sensor and at the base of the foot heater.

Fig.5 Thermographic observation

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Product Inquiries

Sales Department I, Social Solution Division, Sales Group, Fuji Electric Co., Ltd.
Tel: +81-3-5435-7025

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