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Development of refrigerant leak detection technology for mechanical transport refrigeration units using IoT technology

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EXTENDED ABSTRACT

< Abstract >

Refrigerant leakage can generally be detected by monitoring changes in the refrigeration cycle during the operation of air-conditioning equipment. However, for most transport-type mechanical refrigeration units, the compressor is powered by the vehicle's driving engine. Consequently, the refrigeration cycle fluctuates significantly depending on the vehicle's operating conditions. Additionally, detecting engine output or installing dedicated sensors is difficult, so making leakage detection during vehicle operation challenging. Therefore, we developed a technology that focuses on changes in the refrigeration cycle during periods when both the vehicle and refrigeration unit are not in operation, enabling the detection of refrigerant leakage.

< Leak detection technology >

Mechanical transport refrigeration units are typically equipped with sensors for system control. In this study, we calculated analysis value of refrigerant volume using sensor data, as shown Fig.1. By comparing the theoretical refrigerant volume index calculated from the leakage volume, we estimated volume of refrigerant leakage. Sensor data were collected when the vehicle and refrigerator were not in operation, uploaded from the vehicle to a data center using Internet of Things (IoT) technology, and analyzed every minute at the analysis center (Fig.2). This enabled the time-series changes to be captured while eliminating the effects of disturbances as much as possible, thereby achieving highly accurate detection.

Using this technology, year-long field validation was conducted in collaboration with the Tokyo Metropolitan Government and multiple logistics companies. In laboratory evaluations of actual vehicles, the system demonstrated the capability to detect refrigerant leakage within the 30% threshold defined by JRA GL-17. In actual operation evaluations of in-service vehicles, multiple leakage events were successfully detected, confirming the effectiveness of remote monitoring. Because the vehicles are actively used for delivery operations, immediate repairs are often impractical, and leakage rates vary depending on the failure mode. Although precise validation of the 30% detection threshold is not feasible under such conditions, the results suggest that, assuming next-day repair, a recovery rate of approximately 70% can be achieved (Table.1).

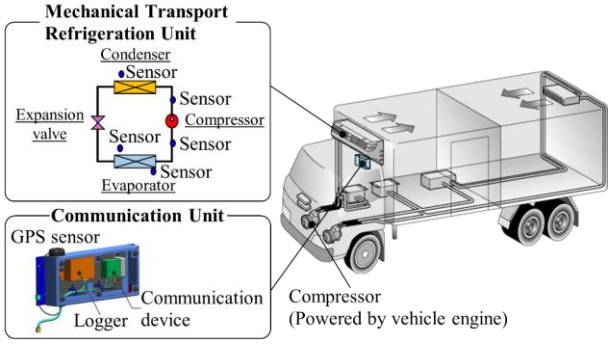

Fig.1 Mechanical Transport Refrigeration Unit

Table.1 Detected Cases in the Actual Operation Evaluations

		Case 1	Case 2	Case 3	Case 4	Case 5
Announcement Date 30% Leakage		'24/2/9	'24/5/15	'24/7/30	'24/9/12	'24/9/18
Repair Date		'24/2/13	'24/5/16	'24/8/8	'24/9/25	'24/9/26
Refrigerant Recovery Rate	Next day	62%	46%	69%	69%	65%
	Repair date	37%	↑	64%	60%	31%

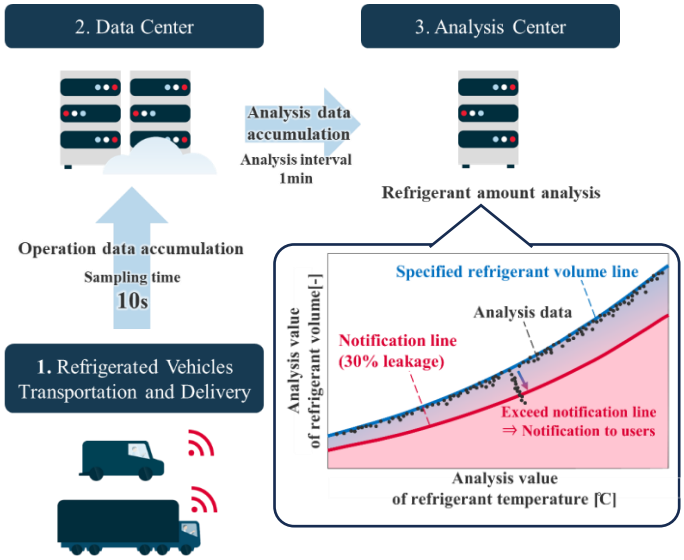

Fig.2 Leak Detection Technology