

## **Executive Summary**

### **KRTC's Light Rail T05 at Cianjhen Star Station**

On May 27, 2020, Kaohsiung Rapid Transit Corporation (KRTC) Light Rail Transit No. T05, a CAF Urbos 3 tram, departed from Hamasen (C14) Station to Lizihnei (C01) Station. At 07:35:16, T05 arrived at Cianjhen Star (C03) Station, the passenger on board reported a burning smell to the driver. At the same time, people on the tram in opposite direction also discovered smoke came out from the roof of T05. At 07:39:15, instructed by the Operation Control Center (OCC), T05 departed without carrying passengers from Cianjhen Star (C03) Station to Lizihnei (C01) Station.

At 07:39:15, T05 departed from Cianjhen Star (C03) Station. At 07:41:06, smoke emitted from the ceiling of the first car (No. 055) of T05, accompanied by sparks and metal frits falling to the floor. At 07:41:22, a warning signal was sent by the smoke detector to the train control and monitoring system and the LED fire detection button on the driving panel lit up.

At the time, there were three staff onboard, one driver, and two commuting employees of KRTC. After the driver reported the incident to the OCC, the OCC instructed the driver to stop the tram. At 07:41:49, T05 stopped by the outer edge on the east side of Kaisyuan Rueitian (C02) Station. Smoke, sparks, and falling metal frits no longer occurred afterward. There were no casualties in this accident.

In accordance with the Transportation Occurrences Investigation Act, R.O.C., and the definition of major transportation occurrences specified therein, the Taiwan Transportation Safety Board was the independent agency in charge of investigating the railway accident. The agencies (institutions)

invited to participate in the investigation included the Railway Bureau of the Ministry of Transportation and Communication, the Transportation Bureau, and the Mass Rapid Transit Bureau (MTBU) of the Kaohsiung City Government, the KRTC, and the Construccions y Auxiliar de Ferrocarriles, S. A. (CAF).

After an investigation on this accident that summarized and analyzed relevant factual data, 12 investigation findings and 13 safety recommendations were obtained, which are presented as follows.

## **Findings**

This investigation report summarizes three categories of investigation findings on the basis of factual information and comprehensive analyses collected during the investigation period: **investigation findings related to probable cause, findings related to risk, and other findings.**

### **Findings related to probable cause**

1. The insulation materials of the LCL filter in the tram in this accident deteriorated along with the period of usage. Consequently, the filter's resistance decreased and increased the current leakage. The temperature of the component rose due to the heat generated by current leakage, leading to further deterioration of these insulation materials. On the day of the occurrence, these materials were likely to entirely malfunction and produce a short circuit. Moreover, the switch of the contactor connecting the LCL filter with the high-capacity NiMH battery string was not designed to trip for the overcurrent. Consequently, following a short circuit in the LCL filter in this tram, the battery strings continued to supply the short current, which generated high temperatures that caused a fire.

## **Findings related to risk**

1. The LCL filter does not belong to the spare part of regular replacement. The maintenance program procedures provided by the manufacturer (CAF) and the KRTC's maintenance procedures did not contain inspection methods and test cycles regarding the filter's insulation value, hence preventing the early detection of insulation deterioration.
2. Before the accident occurred, several alarms of the DC–DC power module equipment in the tram were recorded. However, the alarm information was categorized as not requiring an immediate response. Consequently, the driver and maintenance staff did not detect and address the alarm messages.
3. The fire fighting procedures of the KRTC did not incorporate the CAF Urbos 3 tram's characteristic of triggering the pantograph raised when arriving at a station or the driver's actions of pressing the emergency button to lower the pantograph or shut down the tram power supply when fire occurred, which increased the risk of fire expansion.
4. In the KRTC's tram fire fighting procedures, the driver is assigned the key responsibilities of reporting, broadcasting, evacuation, and firefighting. However, the driver is not given clear authorization or responsibility to stop the tram. Therefore, the opportunity of early response is prone to miss.
5. Since August 2018, the MRTB, Kaohsiung City Government, the KRTC, and CAF have not regularly conducted joint investigations on operation and equipment issues. As a result, failures in equipment with special warranties were unlikely to be addressed, and the opportunity to investigate the cause of the failure in time and monitor improvements was missed.

## **Other findings**

1. The KRTC and CAF had a different understanding of the usage level of the air intake filter of DC–DC power modules, but there was no clear evidence that proved that these different usage levels of air intake filter were the cause of the accident.
2. The working temperature of the LCL filter ranged from approximately 33 to 43 °C, with an average difference of approximately 9.3 °C from the average temperature at the air inlet of the DC-DC power module. The trend of temperature change was consistent with the change in the temperature information published by the Central Weather Bureau and similar to CAF’s experimental results regarding the simulated operating load of the filter.
3. Following a short circuit–induced fire in the LCL filter, the equipment case was melted through, and rainwater on the tram roof caused by the heavy rain on the day penetrated the equipment case through the melted holes, causing a Leidenfrost-effect–induced explosion in the high-temperature copper coil of the LCL filter.
4. The detection and alarm functions of the smoke detector in the tram in this occurrence were operating normally.
5. Having detected a burning smell and smoke, the driver immediately evacuated the passengers. This was in compliance with the company's contingency response regulations. However, the driver did not regard the KRTC employees as passengers and request them to leave the tram as stipulated.
6. The driver stopped the tram outside the Kaisyuan Rueitian (C02) Station to avoid stopping at a location where the pantograph could be triggered to rise. This is in compliance with the CAF driver and operation manuals, which state that the pantograph should be lowered after fire breaking.

## **Safety Recommendations**

### For CAF

1. In consideration of the local operating and usage conditions in Taiwan, enhance the insulation protection specifications of the ACR's LCL filter in CAF Urbos 3 tram, and set relevant standard values. Provide corresponding inspection work items and procedures to the MRTB.
2. Reinforce the overcurrent or over temperature tripping function of the ACR's vehicle electronics for generic applications (VEGA) to ensure the provision of power-off protection measures in case of a circuit abnormality.
3. Reverify the human-machine interface's (HMI's) alert content with particular attention to abnormal ACR indications and elevate the warning level of such indications.

### For KRTC

1. Implement the new inspection work items and procedures added by the MRTB and the manufacturer after the occurrence. Enhance the inspection procedures for the ACR's LCL filter in the CAF Urbos 3 tram.
2. Review which systems or equipment may result in a tram fire, amend the contingency procedures and the authorization of tram stopping for the driver in case of a tram fire, and implement personnel training.

### For MRTB, Kaohsiung City Government

1. Negotiate with the manufacturer. In consideration of the local operating and usage conditions in Taiwan, enhance the insulation protection specifications of the ACR's LCL filter in the CAF Urbos 3 tram, and set relevant standard values. Furthermore, provide the corresponding

inspection work items and procedures to the KRTC and request the proper implementation.

2. Negotiate with the manufacturer. Reinforce the overcurrent or over temperature tripping function of the ACR's VEGA to ensure the provision of power-off protection measures in case of a circuit abnormality.
3. Negotiate with the manufacturer; reverify the content of the HMI's alert with particular attention to abnormal ACR indications, and elevate the warning level of such indications.
4. Investigate the causes of failure in time and monitor the major operation defects periodically through effective communication between the MRTB, the KRTC, and the manufacturer.

For Kaohsiung City Government

1. Supervise the negotiation between the MRTB and the manufacturer. In consideration of the local operating and usage conditions in Taiwan, enhance the insulation protection specifications of the ACR's LCL filter in the CAF Urbos 3 tram, and set relevant standard values. Furthermore, provide corresponding inspection work items and procedures to the KRTC and request the proper implementation.
2. Supervise the negotiation between the MRTB and the manufacturer. Reinforce the overcurrent or over temperature tripping function of the ACR's VEGA to ensure the provision of power-off protection measures in case of a circuit abnormality.
3. Supervise the negotiation between the MRTB and the manufacturer; reverify the content of the HMI's alert with particular attention to abnormal ACR indications, and elevate the warning level of such indications.
4. Supervise the results of the regular contact between the MRTB, the

KRTC, and the manufacturer. Investigate the causes of failure in time and monitor the major operation defects periodically through effective communication.

Note: The language used in occurrence investigation Final Report is in Chinese. To provide general understanding of this investigation for non-Chinese reader, the Executive Summary of the Final Report was translated into English. Although efforts are made to translate it as accurate as possible, discrepancies may occur. In this case the Chinese version will be the official version.