

Study on the Degradation Mechanisms of North American Canister

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North American ORVR regulations require canisters with high working capacity to control evaporative emissions during refueling. In an ORVR canister, fuel vapor is repeatedly adsorbed on activated carbon and desorbed during purge. Adsorption is exothermic and desorption is endothermic. Therefore, cyclic operation can induce internal temperature fluctuations and local thermal gradients. In addition, liquid fuel exposure of activated carbon may directly reduce the available adsorption surface area and degrade working capacity. This study investigates potential degradation mechanisms of ORVR canisters, focusing on thermal excursion, thermal deformation, fuel intrusion, and condensation.

High-temperature driving and high-temperature refueling evaluations were conducted to quantify temperature rise inside the canister. The maximum internal temperature reached 161°C during high-temperature driving, and 150°C during high-temperature refueling. After the thermal evaluations, X-ray inspection was performed. No distinct deformation was observed in the housing or internal structures, even after exposure to 161°C. This indicates that the measured temperature rise was localized and transient under the tested conditions, and that direct structural deformation may not be the primary driver in the evaluated cases.

In contrast, liquid fuel intrusion showed a clear impact on canister performance. As shown in Fig. 8, direct liquid fuel injection into the activated carbon bed (50 cc initially followed by six injections of 100 cc) reduced working capacity by 38% (135 g to 83 g). This confirms that pore flooding can rapidly decrease effective adsorption area. In addition, liquid fuel intrusion is expected to reduce the effective pore volume and to block vapor transport within the activated carbon bed, thereby limiting adsorption during subsequent refueling events. Vehicle-level investigations also suggested that condensation can act as a pathway to liquid fuel formation. For Vehicle “E,” the period during which the canister inlet temperature was lower than the in-tank fuel temperature accounted for 42% of the test duration, indicating a high condensation likelihood. To confirm the occurrence of condensation along the vapor path, a dedicated trap was installed and its temperature was monitored together with the in-tank fuel temperature. Condensation and fuel accumulation were confirmed in the trap, supporting the possibility that condensed fuel can be transported toward the canister under certain thermal boundary conditions. Furthermore, fuel properties significantly affected condensation severity, as evidenced by differences in the distillation behavior of the evaluation fuels (Fig. 12).

During the Death Valley vehicle evaluation, fuel accumulation of 40 cc was observed in a separately installed trap used to quantify liquid fuel carryover. Because the fuel level was below 50% at the time of accumulation, direct overflow into the in-tank valve was considered unlikely, and the accumulated fuel was presumed to originate from condensation of gasoline vapor. To verify this mechanism, a dynamo-chamber evaluation was conducted with the trap installed at the same location. The condensation behavior was evaluated by comparing the in-tank fuel temperature with the trap temperature during the driving sequence, and condensed fuel accumulation increased when the fuel temperature exceeded the trap temperature. Notably, the condensed fuel amount in the chamber evaluation reached 120 cc, which was three times higher than that observed in the Death Valley evaluation. To identify the cause of this discrepancy, the fuel distillation behavior was examined. At the same final fuel temperature of 55°C, the evaporated fraction of the chamber-test fuel was approximately three times higher than that of the evaluation fuel used in Death Valley, consistent with the threefold increase in condensed fuel accumulation (Fig. 12). This result indicates that condensation severity can vary significantly depending on fuel distillation characteristics even under comparable thermal conditions.

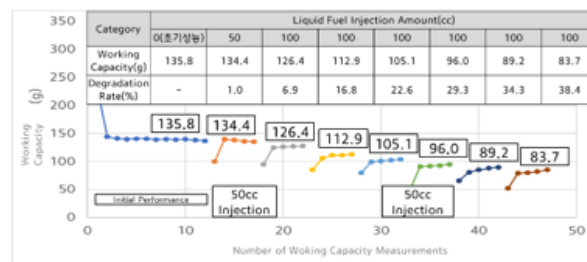


Fig. 8 Impact of Fuel Permeation on Canister Working Capacity

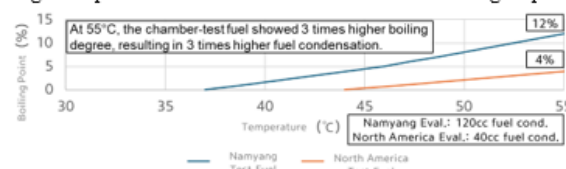


Fig. 12 Boiling-point characteristics of the evaluation fuels