TECHNICAL NOTE

FUEL CELL ELECTRIC BUSES

Cold weather operation

Performance in Cold Climates

Fuel cell buses offer an emissions-free alternative for transit operators without compromising on the performance and utility delivered by conventional diesel buses. Part of this no- compromise experience is being able to operate fuel cell buses in all weather conditions.

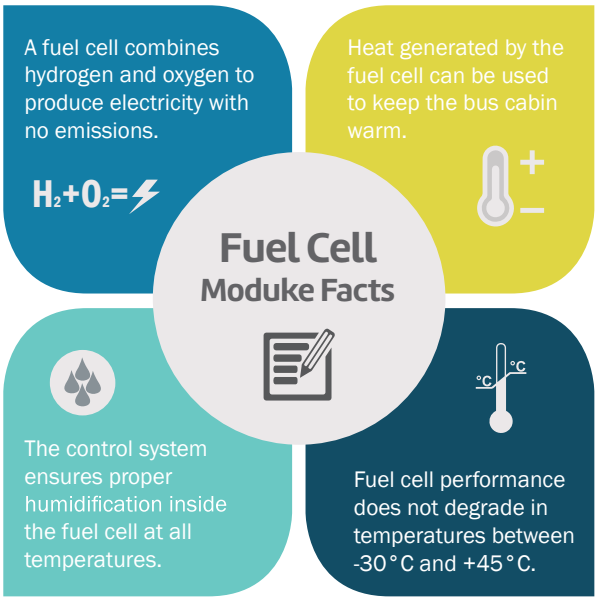
Fuel cell buses powered by Ballard's FCmove® engines have operated over 150 million kilometers and are well proven in extreme climates. During deployments in cities including Edmonton, Alberta; Poznan, Poland; and Bolzano, Italy, fuel cell bus fleets have provided reliable service in cold weather conditions without impact on range or performance, as compared to battery electric buses.

Operating the FCmove® Fuel Cell Engine in Cold Weather

When in operation, although the outside ambient temperature may drop below 0°C, the heat generated from the fuel cell prevents the systems from freezing. This useful heat enables operation even when the air temperature drops as low as -30°C and it can be used to keep the cabin or the battery compartment warm.

Ballard's FCmove® power engine can be stored at temperatures as low as -40°C. A 'cold weather kit' enables fast start-up down to -20°C and the control system employs freezing countermeasures to prevent the conversion of water to ice, and subsequent potential damage due to ice expansion.*

** For optimum stack performance, limit the number of freezing events.*



Storage in Cold Weather

When the bus is parked, the fuel cell isn't consuming fuel, and so is no longer generating heat, allowing internal temperatures to drop. Ballard's FCmove® fuel cell control system looks after the fuel cell even while the bus is out of service.

Short Stops

If the bus is parked for a short period of time, the insulation and the inherent mass of the fuel cell can hold heat for several hours. In freezing temperatures, the bus can be idle or parked for short periods without the need for the control system to initiate freeze protection measures. In this situation where the internal temperature remains above freezing, the bus can be started normally without warm-up time.

Longer Stops (>3 hours*)

If the FCmove® engine control system observes the internal temperature dropping towards 0°C, an internal sequence of actions can be initiated to prepare for freezing. Water is purged from lines, and components are dried out to remove water from the entire fuel cell system. In this dry, freeze-protected state, the bus can remain in freezing temperatures without damage to the fuel cell.

Photo Credit: BC Transit

Start-Up in Below Freezing Temperatures

Once frozen, the fuel cell system can be started after warming the internal temperature above freezing.

In order to allow a fast start-up while temperature is still below freezing, the fuel cell should be kept warm during down- time. FCmove® engines offer several "cold protection" options allowing immediate start-up down to -20°C.

1. Plug-In Resistance Heater

If the bus can be parked near a utility grid power outlet, an optional plug-in freeze protection system keeps the fuel cell within a temperature range that allows it to start up immediately when left for long periods of time in freezing conditions. If there is no access to a utility grid connection, energy from the bus battery can maintain the fuel cell temperature above freezing. An estimated 250W to 800W is required to maintain the module above freezing at -20°C.

2. Automatic Start-Up of the Fuel Cell System

The drive system can be programmed to start the FCmove® engine automatically for a pre-set period of time when the control system observes the internal temperature approacing 0°C. As it operates, the fuel cell will generate heat to maintain the module above freezing. The module will also produce electricity which can be used to power the HVAC system to pre-warm the bus cab in prior to service.

** Specific time varies with outside temperature.*

About Ballard Power Systems

Ballard is a world leader in the development, manufacture, sale, and servicing of PEM hydrogen fuel cells. With more than 44 years of experience, Ballard represent decades of innovation and engineering leadership in clean energy solutions. Our fuel cell technology powers buses, trucks, trains and ships, as well as stationary power systems.

To learn more about Ballard, please visit: www.ballard.com

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