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Short Title	Storage Procedures and Winterization
Full Title	Crosswind/Baseload Power Hub Fuel Cell Package Storage Procedures and Winterization
Abstract	This document presents the options for both extremely high ambient temperatures and below freezing conditions. In both cases, if supplied with power, the FC package can both ventilate and heat the internal space. If power is not available, procedures are available for winterizing the fuel cell container. The winterization process requires some hydrogen to accomplish and to restore the fuel cell to operating conditions, Ballard personnel is required.

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1.0 Purpose and Scope

The purpose of this document is to outline storage procedures and winterization for the Baseload Power Hub Fuel Cell Package container.

The goal for the fuel cell package container internal temperature is to stay between 5 and 40 degrees. The lower bound for the internal temperature is driven by the requirement to keep the fuel cell modules above freezing and the upper bound is the highest ambient temperature for electronics components.

The reader is expected to be familiar with the following documents:

- B01 General Arrangements
- C03 Process and Instrumentation Diagrams
- C06 Single Line Diagrams

2.0 Reference Documents

Table 1: Reference Documents

Document ID	Document Title	Revision
B01	General Arrangement	Newest
C03	Process and Instrumentation Diagram	Newest
C06	Single Line Diagram	Newest
E14	Electrical Load List	Newest

3.0 Summer Storage Options

The FC package can self-ventilate during stand still for extended periods in very hot conditions.

Under normal conditions, no action is needed but days with high ambient conditions and direct sun internal ventilation is required.

3.1 Ambient Conditions

If the ambient conditions do not exceed 35 degrees and direct sun is not expected, no action is needed.

3.2 Excessively hot days.

If ambient conditions exceed 35 degrees and periods with direct sun is expected, the container should be allowed to self-ventilate to manage internal temperatures.

To do this, the container should be connected to AUX power and be allowed to run the fans. The expected power consumption is approx. 2kW.

If it is not possible to allow AUX supply to the container, a sun-shield can also be erected as an alternative. Please confer with Ballard.

4.0 Winter Storage option overview

The FC package can be stored in several different ways:

- Fully Off
  - Everything depowered and disabled, prepared for long term storage.
- Control system active, heating disabled.
  - Control and safety system enabled.
  - Heating system disabled.
  - Fuel Cells winterized.
- Standard with Winterization
  - Control and safety system enabled.
  - Heating system enabled.
  - Fuel Cells winterized but kept above freezing by the heating system.
- Standard
  - As above, but fuel cells are not winterized.

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Each of the options are outlined with pros ands cons are outlined in the following sections.

Table 2: Storage Option Overview

System	Fully Off	Minimum	Standard with Winterization	Standard
Control System	Off	On	On	On
Safety System	Off	On	On	On
Heating	Off	Off	On	On
Fuel Cell Modules	Winterized	Winterized	Winterized	Normal

5.0 Winter Storage Methods

5.1 Fully Off

In this storage method, everything is disabled, and fuel cell modules are winterized.

This method sets the least requirements to the storage facility, but the largest pre and post storage work, including work from Ballard service technicians.

Table 3: Fully Off – Pro/Con list

Pro	Con
No requirements to storage facility	No monitoring of package condition
Can handle down to -30°C	Requires Ballard intervention to restart and recondition fuel cell modules
No power demand from AUX supply	Cannot deliver full power before reconditioning cycle is completed on modules
	No safety system active

5.2 Shipping

For shipping under known conditions or other short storage periods, the winterization can be skipped if the ambient conditions are known and guaranteed to be non-freezing.

This will save personnel hours both before and after the storage period to prepare the fuel cells for the winterization and to restore them from the winterized state after the storage.

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5.3 Minimum Power

In this storage method, the control system is powered, and fuel cell modules are winterized. The heating system for the container is disabled to minimize power usage.

This method has minor requirements to the storage facility, but still has the same pre and post storage work as the no-power solution, including work from Ballard service technicians.

Table 4: Minimum Power – Pro/Con list

Pro	Con
Control and Safety Systems active	Requires AUX Supply active
Can handle down to -30°C	Requires Ballard intervention to restart and recondition fuel cell modules
Monitoring of FC package condition	Cannot deliver full power before reconditioning cycle is completed on modules
Low power demand	

5.4 Standard with Winterization

In this storage method, the control system is powered, and the heating system is also active, thus maintaining the container at a above-freezing temperature. This will consume additional power if ambient conditions are around or below freezing.

Fuel Cell Modules are winterized to prevent damage in the cause of a prolonged power outage at the storage site if conditions are uncertain or response time to outages are expected to exceed a few hours.

This method has some requirements to the storage facility, but still has the same pre and post storage work as the no-power solution, including work from Ballard service technicians.

Table 5: Standard with Winterization – Pro/Con list

Pro	Con
Control and Safety Systems active	Requires AUX Supply active, up to 20kW
Can handle down to -20°C	Requires Ballard intervention to restart and recondition fuel cell modules
Monitoring of FC package condition	Cannot deliver full power before reconditioning cycle is completed on modules

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No damage if loss of power occurs	Higher power demand

5.5 Standard

In this storage method, the control system is powered, and the heating system is also active, thus maintaining the container at a above-freezing temperature. This will consume additional power if ambient conditions are around or below freezing.

Fuel Cell Modules are *NOT* winterized to prevent damage and will be damaged in the cause of a prolonged power outage in freezing conditions.

Damage can be prevented if personnel can respond and restore power before the container freezes. That is estimated to take about one day, shorter on very cold days.

This method has some requirements to the storage facility, but no requirements for Ballard personnel or pre/post storage procedures.

Table 6: Standard – Pro/Con list

Pro	Con
Control and Safety Systems active	Requires AUX Supply active up to 20kW
Can handle down to -20°C	Higher power demand
Monitoring of FC package condition	
Ready for operation with no special actions	

6.0 Procedure for Winterization of FC Module

The procedure for winterizing a FCwave module is known internally as a dry-out of the module.

The procedure for doing the winterization is described in this section, split into what is required for the entire FC package and what is needed for the FC module.

6.1 Fuel Cell Preparation

The fuel cell module requires the surrounding support systems to be active, as described in the following section.

The fuel cell module itself has control interfaces capable of starting the winterization process.

This is accomplished by starting the fuel cell module without load applied and sending a command signal to start the sequence. This then causes the fuel cell to disconnect its DC bus and use internal power to displace water out of the fuel cell membrane by a hot, dry operation regime.

Prior to installation or if needed, a Ballard service technician can use portable equipment to start the fuel cell and perform the winterization without the primary AC connection or DC link active.

When it is desired to operate the fuel cell as normal again, a reconditioning is needed to achieve full performance.

6.2 Requirements – Standard Installation

The FC package requires several interfaces to be active to perform the winterization:

- MV Link must be active and capable of providing <10kW of power for the following systems:
  - MV Transformer Energization
  - Electronics cooling
  - Process cooling (at idle)
  - Startup power for the fuel cell module
- Alternatively, a Ballard service person has portable equipment which allows the fuel cell to start.
- Gas supply must be able to provide H2 for the winterization process.
  - Typically, <200g H2 pr module.
- Liquid drain must handle displaced water.
  - Typically, <200mL pr module

The process takes about 5-7 minutes pr module and can be done in parallel.

6.3 Requirements – Ballard Service Technician Onsite

If the standard installation is not available or not yet commissioned, a Ballard service technician can accomplish the winterization with portable equipment:

- An on-site 400V 3phase power must be available for the service technician to use.
- If the hydrogen installation is not ready, a portable gas bottle (50L) can provide enough hydrogen to perform dryout for an installation of 6 modules.
- Liquid water can be drained or collected in a bucket and disposed of.

- Typically, <200mL pr module

The process takes about 10-15 minutes pr module.

6.4 Procedure – Standard Installation

Using the operator interface for the FC package, perform the following steps.

1. Coordinate with BLPH to enable DC link.
2. Enable 24V to all modules that needs dryout.
3. Start DC Link
4. For each module, start module with 0kW setpoint.
    a. When running, within 10 seconds of reaching “Running”, send “Dryout” command bit.
5. Allow module to perform dryout sequence. It will take approximately 2 minutes pr module.
6. Multiple modules can perform dryout sequence simultaneously.
7. Disable DC link.
8. Depower modules.

6.5 Module Restart

Refer to service manual for FCwave modules.

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7.0 Periodic Visual Inspection

When the FC package is stored for extended periods without operation, periodic visual inspection is desired.

The purpose of the inspection is to confirm the condition of the container and to spot any issues before they develop into more severe problems.

7.1 Interval

The package should be inspected at least every 14 days (every other week) and after each significant weather event (storm, blizzard, etc).

7.2 Tools

The person inspecting the package shall wear all relevant PPE, as stated on the warning placards and local HSSE requirements.

The person should bring the following tools:

- Flashlight or inspection light
- Camera or other device to document issues
- Container access keys
- Electrical cabinet keys

7.3 External Inspection

The person should walk around the package, inspecting the following items:

- Accumulation of dust and grime
    - Any build up of dust and grime
    - Particularly around air intakes and access doors, should be removed.
- Signs of coolant spillage
    - Coolant contains blue dye, spillage will lead to blue discoloration or stains
    - Inspections sites include:
        - Primary coolant connection between 40ft container and coolant skid
        - Hydrogen heater tank
- Cables and cable trays
    - Any cables not firmly seated in cable tray or other mechanical fasteners.
- Intake and outlet louvres
    - Both on 40ft and 10ft container
    - Should be firmly closed, with no visible openings.

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7.4 Internal Inspection – 40ft Container

The person should open the door to the 40ft container and step inside, while minimizing dust and dirt into the container.

- Liquid spills
  - Inside on the container door, below false floor
  - LT coolant rack
  - HT coolant entry point (below ventilation intake fans)
- Cable inspection
  - Cable visual inspection for damage and disturbance
- Dust
  - Vacuum any dust or debris from inside container.
  - DO NOT use compressed air to shift dust around.
- Fuel Cell Module Inspection
  - Using electrical cabinet key, open FCwave front panel
  - Using inspection light, inspect bottom of cabinet for dust or liquid spill.

7.5 Internal Inspection – 10ft container

Internal inspection for dust and liquid.

1. Inside control panel access door, press the emergency stop.
2. Open container end door, and without stepping inside the container, inspect the floor for liquids and debris.
3. Close container door, reset emergency stop circuit.

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