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Short Title	G11 – Reliability and Availability
Full Title	Reliability and Availability for the Fuel Cell container (1MW) for Crosswind Baseload Power Hub

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Revision Record

Rev #	Description	Revised By	Date
1.0	NA,		
2.0	Comments and descriptions for data in Appendix 1 added	JTA	Sept 2025

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1.0 Purpose

The purpose of this document is to give an impression of reliability and availability for the Fuel Cell container (1MW) for Crosswind Baseload Power Hub.

As the Fuel Cell container (1MW) for Crosswind Baseload Power Hub is a first of its kind system, there are no reliability or availability data covering the overall Fuel Cell container (1MW) system.

Most critical components regarding reliability are the FCwave™200kW fuel cell modules. Hence the data presented in appendix 1 is the maintenance plan including Preventive Maintenance intervals for this module.

2.0 Appendix

Table 1: Appendix Documents

Document ID	Short ID	Document Title	Source
SPC5114412-0A	Appendix 1	Maintenance Plan, FCwave™ 200kW	BPSE

3.0 Maintenance Plan for FCwave™ 200kW

The data presented in appendix 1 only coverers the FCwave™ module.

It is required to follow the maintenance plan to ensure trouble-free operation.

Maintenance intervals are influenced by the operating pattern for the system.

Background for the maintenance plan is that the system operates up to 6000 h/year (1500 hours quarterly) and that preventive service is carried out 4 times / year by trained service technicians.

4.0 Appendix 1 Maintenance Plan for FCwave™ 200kW

Maintenance Plan, FCwave™ 200kW

SPC5114412-0A

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Revision Record

Rev.	CO	Description	Date
0A	CO40908	Initial release	2024-01-03

Purpose of Document

The purpose of this document is to inform about the Preventive Maintenance intervals for the FCwave™ 200kW fuel cell module. It is required to follow the maintenance plan to ensure trouble-free operation during the lifetime of the FCwave™ module.

Conducting maintenance requires a certain level of competences. It is assumed that the owner or operator of the FCwave™ employs the right technical skills.
To ensure that the activities are carried out in a correct and safe manner, Ballard offers a dedicated FCwave™ training program consisting of several levels.
It is considered mandatory having participated in- and successfully passed such training prior to executing any work on the FCwave™.

The actual execution is governed by a task and interval reference, the Maintenance Plan, and supported by in-depth instructions collected in the always current version of the Fuel Cell System Service Manual, FCwave™ 200kW.

Conditional Inspections

In the Maintenance Plan below, several routine inspections are listed which shall be carried out according to the specified intervals.

These checks and inspections are intended to support an early-stage detection of any deviation of a condition, which later can cause a malfunction and/or need for intrusive corrective actions.

Conditional Inspection Plan

Covered by sensors in container system

Task	Interval *Whichever comes first		Comments
	Hours	Month(s)	
High Temperature Coolant Sub-system			
Check **coolant level indicator** on header tank.	250	1	Check HT coolant level is between minimum and maximum.
Check **cooling sub-system**.	250	1	Visual inspection for signs of coolant leaks.
Check **stack coolant** conductivity.	1.500	3	Replace **DI filter** (resin cartridge) if conductivity exceeds specification of 5 µS/cm @20°C.
Check **coolant tank level switch**.	6.000	12	Functional check. Replace if needed.
Check **coolant particulate filter** (wedge wire screen) for damage.	6.000	12	Clean filter. Replace if necessary.
H_2 Enclosure and Stack Sub-system			
Check **H_2 Enclosure water ingress sensor**.	3.000	6	Functional check as part of safety verification. Replace if necessary.
Check **differential pressure safety switch**.	3.000	6	Functionality check as part of safety verification.
Check **ventilation inlet flow switch**.	3.000	6	Functional check as part of safety verification.
Check **H_2 sensors**.	3.000	6	Functionality check as part of safety verification. Replace if necessary.
Check **enclosure ventilation fans**.	3.000	6	Functionality check as part of safety verification. Replace if necessary.

Process Air (Cathode) Sub-system			
Check **air filter w/ Mass Air Flow (MAF) meter**.	6.000	12	Replace if necessary.
H_2 Fuel (Anode) Sub-system			
Check **Hydrogen Recirculation Blower (HRB)** for oil leaks. Check elastic coupling element for wear.	6.000	12	Check HRB for oil leaks and replace if necessary. Inspect coupling for wear and replace if clear signs of damage to coupling material.
Check **HRB motor** for signs of wear to bearings, noticeable by wear on coupling element.	6.000	12	Check for vibration levels depending on RPM of the motor.
Cabinet Assembly			
Check **cabinet doors air filters**.	1.000	2	Check condition and replace if necessary.
Check **cabinet water ingress sensor**.	3.000	6	Functional check as part of safety verification. Replace if necessary.
Check **smoke detector**.	3.000	6	Functional check as part of safety verification. Replace if necessary.
Electrical Sub-system			
Check **electrical wire harness**.	6.000	12	Visual inspection of damage to insulation from rubbing against fixation or other objects.
Check **Linear Heat Detector (LHD) / fire wire**.	6.000	12	Visual inspection of visible fire wire. Check functionality. Replace if damage to insulation or lacking function.

Periodic Exchange of Components Due to Wear

Compared to other means of energy provision, the Ballard FCwave™ fuel cell only require a minimal number of components to be changed with fixed intervals in the, prolonged, period between the need for conducting a major overhaul.

Periodic Exchange Plan

Task	**Interval** *Whichever comes first		**Comments**
	Hours	**Month(s)**	
High Temperature Coolant Sub-system			
Change **DI filter** cartridge.	6.000	12	Replace DI filter cartridge.
H_2 Enclosure and Stack Sub-system			
Change **purge valve** due to wear as consequence of accumulated activations.	12.000	24	Replace purge valve.
Process Air (Cathode) Sub-system			
Change **humidifier assembly**.	5.000	10	Replace.
Change **cabinet door air filters**.	6.000	12	Replace filters.
Change **air filter w/ MAF meter**.	12.000	24	Replace filter and sensor.

Components Replaced Due to Safety

Given the FCwave™ module is operated on hydrogen, a corresponding number of dedicated hydrogen sensors are part of the safety system as well as the smoke detector installed in the FCwave™ module cabinet.

Safety Component Exchange Plan

Task	Interval *Whichever comes first		Comments
	Hours	Month(s)	
H_2 Enclosure and Stack Sub-system			
Change **H_2 sensors**.	6.000	12	Replace.
Cabinet Assembly			
Change **smoke detector**.	6.000	12	Replace.

Major Overhaul

Ballard scope

At a certain point of time, just like for any other type of machinery having operated for thousands and thousands of hours, the need for a Major Overhaul is present.
The indication of major overhaul is either by an increased consumption of hydrogen to produce a certain amount of energy, or the module can no longer output maximum energy according to the specification.
The Ballard Customer Care department can assist with evaluation of such need, as well as predict the activity in due time, if a service contract is established which include remote data monitoring.

The upper compartment containing the actual fuel cell stack can be removed by Ballard service technicians within a short period of hours and replaced with a 1-to-1 exchange unit containing a fully refurbished, tested, certified and trouble-free unit.

Owner scope or outsourced to Ballard

The lower unit is considered the BOP, Balance of Plant, for the fuel cell. It contains the systems required for the fuel cell to produce energy, such as air supply- and conditioning plus cooling system consisting of pump, valves, pipes, and heat exchanger.

The BOP components are standard heavy duty industrial designs which can be maintained and serviced by competences with a basic technical experience of marine, industry and/or automotive background, plus the specific training. As such, the required activities for these components at the time of Major Overhaul, can be scheduled in a way causing minimal intrusion of the operation. This is a recommendation however it will be based on owners preferred principle.

Major Overhaul Plan Owner Scope

Task	Interval *Whichever comes first		Comments
	Hours	Month(s)	
High Temperature Coolant Sub-system			
Change all HT coolant.	25.000	60	Replace cooling water as part of major overhaul and stack replacement.
Replace DI filter cartridge.	25.000	60	Replace DI filter.
Check coolant particulate filter (wedge wire screen).	25.000	60	Check for damage and clean. If damaged or perforated, replace with new.
HT coolant pump.	25.000	60	Replace shaft seal, O-rings, and gaskets or entire pump based on owners preferred principle.
HT coolant heat exchanger.	25.000	60	Evaluate the need for de-acidification or backflushing of customer side of heat exchanger.
Low Temperature Coolant Sub-system			
LT coolant condition – replace if necessary.	25.000	60	Evaluate the need for de-acidification or backflushing depending on visual signs of contamination or impurities.
Process Air (Cathode) Sub-system			
Replace cabinet doors air filters.	25.000	60	Replace filters.
Check air filter w/ MAF meter.	25.000	60	Replace filter and sensor.
Replace humidifier assembly.	25.000	60	Replace.
Electrical Sub-system			
Check electrical wire harness and power cables.	25.000	60	Visual inspection of damage to insulation from rubbing against fixation or other objects.
Check Linear Heat Detector / fire wire.	25.000	60	Visual inspection of fire wire in lower cabinet. Replace entire loop if damage to insulation.
Cabinet Assembly			
Check cabinet water ingress sensor.	25.000	60	Functional check, replace if necessary.
Clean cabinet.	25.000	60	Clean internal surface for collected dust and impurities.