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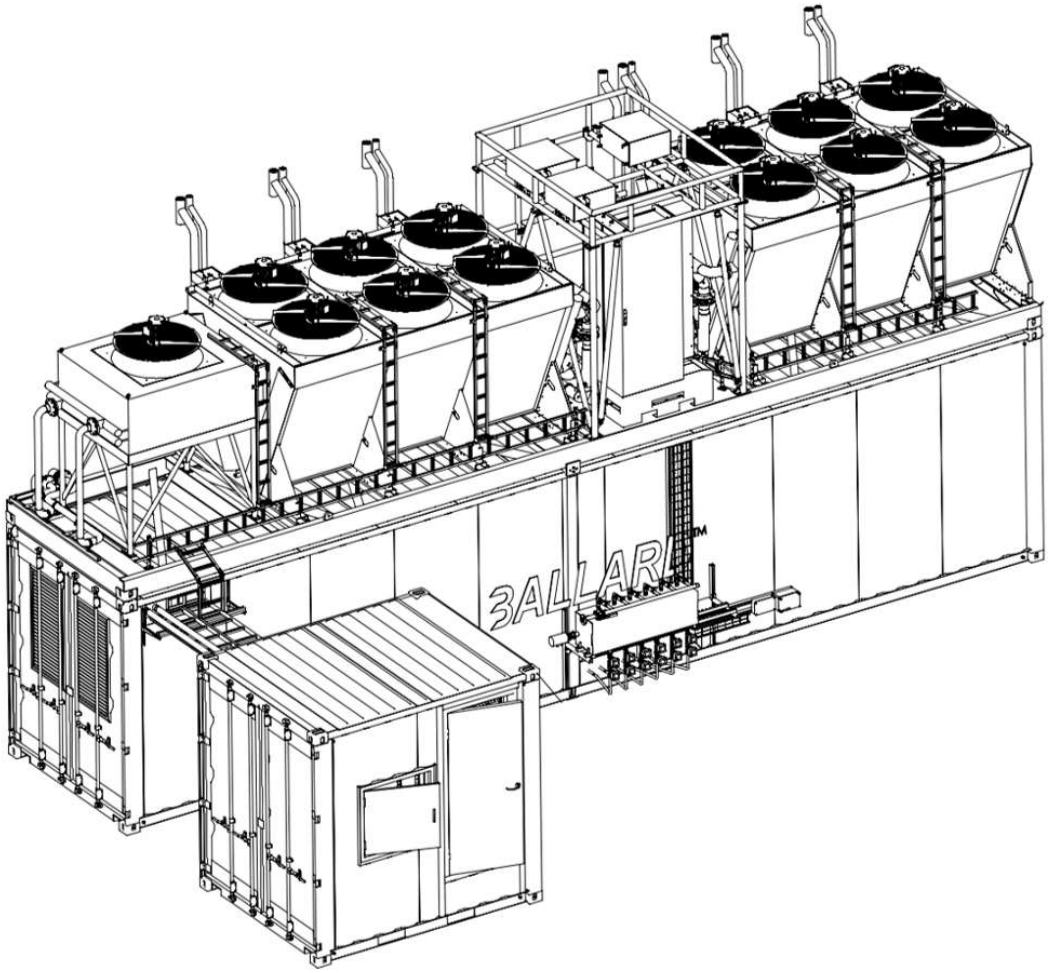
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FC PowerGen 1000kW

Part no.: 601456B-7002362

Configuration: 40ft Fuel Cell Container w. 6 FCwave's
10ft Converter Container, 6,6 kVAC

Service and Maintenance Manual



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1.0 Disclaimer

NOTE: READ THIS BEFORE ATTEMPTING ANY PROCEDURES DESCRIBED IN THIS MANUAL

There are inherent risks in the operation of a fuel cell module that can result in death or bodily injury or loss or damage to property. It is therefore necessary for the customer to take all prudent safety precautions in the installation, use, and maintenance of this device. Persons who install, operate, and service the device are required to be technically qualified and experienced in working with electrical equipment, compressed gases, and H2.

This manual includes certain safety guidelines and recommendations; however, this manual is not intended to cover all situations. The customer is responsible for determining the suitability of the customer's particular design or application, and for ensuring the safe operation, maintenance, and storage of the device and any systems into which it is integrated. Ballard Power Systems Europe A/S ("BPSE") cannot be responsible for the use of the device in ways, or as part of systems, that deviate from the operating recommendations in the manual. The customer is responsible for being aware of, and complying with, all applicable laws and regulations. BPSE has limited its liability for damages incurred by the customer or its personnel in the contract documents pursuant to which the device is provided to the customer. Please refer to those documents for additional information.

Procedures described in any part of the manual can only be attempted once the customer has read this entire manual. Failure to follow any instruction or recommendation could result in death or bodily injury or loss or damage to property.

BPSE intends for the device to be installed, operated, and serviced only by approved technically qualified and experienced people who understand the principles of fuel cell technology, are aware of the safe operating limits of fuel cells, and are familiar with the risks posed by operating a fuel cell module. BPSE relies on customers to use their own knowledge and experience when installing, operating, and servicing the device. BPSE also relies on the people using this manual to be familiar with common terms and abbreviations used in the manual.

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2.0 General Information



Service and Maintenance personnel must read and understand the Operator Manual mentioned in section 2.4 prior to activities covered by this manual.

2.1 Manual Purpose and scope

This Service and Maintenance Manual for the FC PowerGen provides guidance and instructions for routine inspections, testing, and maintenance tasks necessary for the safe and reliable operation of the system throughout its operational lifetime.

It covers topics such as:

- Safety protocols
- System Description
- Preventative Maintenance

Excluded from this manual are specific Service-, Maintenance-, and Repair- instructions. These are separate documents, reserved for trained and authorized personnel.

2.2 Intended audience

The intended audience for this manual is persons involved in service and maintenance of the FC PowerGen system.

Technicians and maintenance personnel who are responsible for servicing and maintaining the system must be authorized and trained by Ballard to perform service and maintenance according to this Manual, referred documentation, and instructions.



Technicians and Maintenance personnel must read and adhere to this manual when performing service and maintenance on the system.

Audience Key characteristics:

- **Technical proficiency**: The intended audience possesses a strong technical background and expertise in Fuel cells and electrical systems.
- **Authorized personnel**: Technicians and maintenance personnel are authorized by the manufacturer to access and use the Service and Maintenance Manual.
- **Training requirement**: The service responsible must use technicians who have undergone specific training programs provided by the manufacturer to ensure proficiency in servicing and maintaining the system safely.
- **Responsibility**: The service responsible must ensure the execution of routine inspections, testing, components change, and other maintenance tasks necessary for the safe functionality of the system.

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2.3 Training Level Certification

2.3.1 System service

Service on the system, excluding the FCwave, may only be performed by Ballard authorized personnel listed in the service authorization list and only according to the service tasks for which they are approved.

2.3.2 Fuel cell service

Personnel performing service on FCwave must be trained according to Ballard training levels:

Tier 1 – Service technicians and fuelers

Tier 2 – Service technicians and mechanics

Tier 3 – Senior Service technicians and Engineers

Details of roles and responsibilities are reinforced by Ballard's standard Service Level Agreement. Contact Ballard for details regarding training.

2.4 Manual series

The Manual Series provides manuals covering different life-phases of the system, as defined in Table 2-1:

Table 2-1: Manual series contents

Document no.	Title	Brief purpose description	Intended user(s)
Ballard: 7003672 CW: K559-2254-CWIWP4202202-R01-002	Transportation and Handling Manual	Enables safe, land-based, transport and handling from manufacturer to designated site.	Personnel qualified in preparation of, handling, and transport of freight.
Ballard: 7003718 CW: K559-2254-CWIWP4202202-N01-001	Integration Manual	Enables integrators to design a designated site and subsystems required within the intended use and limits of the system.	Integrators partaking in designing the designated site and subsystems, and commissioning.
Ballard: 7003717 CW: K559-2254-CWIWP4202202-N01-002	Operator Manual	Provides information to personnel for safe operation of the solution, instructions for operator-based maintenance, safety rules and recommendations	Operators, Integrators, Installers, Service and Maintenance personnel, personnel working in or near the system, and persons instructing visitors.
Ballard: 7003719 CW: K559-2254-CWIWP4202202-N01-003	Service and Maintenance Manual	As described in section 2.1	As described in section 2.2

Ballard Power Systems Europe (BPSE) may update the provided manuals on an ongoing basis.

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2.5 Ballard Aftersales Service

Contact information on Ballard Aftersales Service can be found at:
https://www.ballard.com/support/

2.6 Hazard Symbols

Hazard symbols throughout the manual indicate objectives or potentially dangerous situations.

Table 2-2: Hazard symbols

	**MANDATORY ACTIONS**: are marked with blue action-points. This indicates actions that must be performed. Ignoring may result in an accident, which could cause damage to equipment or other property, and could cause bodily injury if not promptly detected and remedied.
	**PROHIBITIONS**: are marked with red prohibition-signs. This indicates a forbidden action. Ignoring may result in immediate bodily injury or loss of life or could cause damage to equipment or other property
	**WARNINGS**: are marked with yellow triangles and/or square warning. Indicates hazards that may result in an accident, which could cause immediate bodily injury or loss of life or could cause damage to equipment or other property.
	**CAUTION** in this manual indicates actions that may result in an accident, which could cause damage to equipment or other property, and which could cause bodily injury if not promptly detected and remedied.
	**ELECRICAL HAZARD** Obey ALL warnings, cautions, and safety instruction related to electricity. Failure to do so may result in electrical shock leading to personal injury or death.

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2.7 References

Throughout the manual are referrals to separate documents. These references documents are available on the BPSE after sales Service Portal.

Should a document not be available, contact BPSE.

Table 2-3: Reference documents

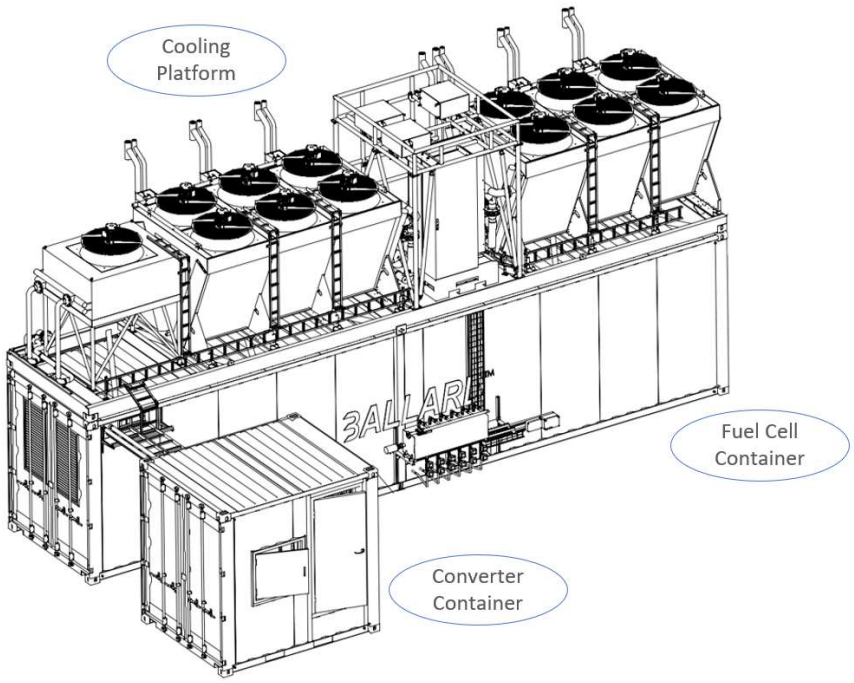
Document no.:	Document name:
7003724 (attached)	Maintenance Plan
K559-2254-CWIWP4202202-D05-001Rev001	Material Safety Data Sheets
K559-2254-CWIWP4202202-C99-001Rev002	Hydrogen Safety Concept
K559-2254-CWIWP4202202-K02-001Rev002	Equipment hazardous area certificate and schedule
K559-2254-CWIWP4202202-B99-003Rev001	Structural calculations - false floor
K559-2254-CWIWP4202202-B01-001Rev009	General Arrangement
K559-2254-CWIWP4202202-C03-001Rev006	P&IDs
K559-2254-CWIWP4202202-C06-001Rev007	Electrical Single Line Diagram
K559-2254-CWIWP4202202-E03	Electrical Cabinet Documentation
K559-2254-CWIWP4202202-N01-005Rev001	Lockout Tagout
N99 - MAN001Rev1.1.1	FCwave – Service and Maintenance Manual
K559-2254-CWIWP4202202-C07-001Rev002	Cause and Effects Chart

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3.0 General System Description

The system is a modularized power generator based on a number of FCwave™ Fuel cell units.
The FC PowerGen consists of the following main components:

Figure 1: Major components overview



Short descriptions of major components can be found in Table 3-1

Table 3-1: Major components of the machine (See Figure 1)

Component	Short Description
Fuel Cell Container	Based on a 40ft HC container, modified to a machine housing with access, ventilation, light safety etc. The container holds 6 FCwave modules with installation, internal 400VAC power supply for complete Balance of Plant components, main controller, LT pump system and DC/DC converters.
Cooling Platform	40ft Cooling Platform with service platform. 2 individual HT radiators dimensioned to the specific solution 2 individual HT pump-systems 1 LT radiator
Converter Container	Based on a 10ft HC container, modified to a machine housing with access, ventilation, light, safety etc. Holds DC to AC grid-supplying power electronics, Isolation transformer, and Grid Main Breaker.

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4.0 Safety

4.1 General safety



The reader of this manual shall read the operator manual mentioned in section 2.4 for additional information on general function and safety, as a supplement to the manual.

The applicable service procedure must always be consulted before any service activity is performed.

Any safety related information herein must be followed.



All service technicians must understand and comply with good workmanship and safety procedures generally associated with machinery service, even if these procedures are not specifically stated in this document.

While working on the system, there should always be more than one person present on-site.

4.2 Personal Protective Equipment

The service technician must bring and use appropriate PPE.

In general:

- Safety shoes are mandatory.
- Hearing protection must be available and used when the system is operational.
- Fire inhibited clothes must be used when working on the electrical system.
- Helmets must be used when hoisting equipment inside the Fuel Cell Container.
- Helmets and Fall arrest equipment must be used when working at heights.
- Suitable gloves and eye protection must be used for working with coolant.
- Suitable gloves must be used for where risk of cuts is present, i.e. under the raised floor because of sharp edges.
- Suitable tools for working on live voltages – as per EN 60900.

Procedures may specify additional PPE.

4.3 Corrective maintenance

In situations where errors arise because of defective or worn-out parts, contact Ballard for support. Corrective maintenance must be done by authorized personnel.

4.4 Retrofitting and modifications

Retrofitting and modifications of the system shall be in collaboration with Ballard. Contant Ballard for support. Ballard will not take responsibility for any non-approved items applied; it is the responsibility of the applying entity. Unapproved modification may affect the warranty on the entire system.

4.5 Spare and wear parts and consumables

Using spare parts and consumables from third party manufacturers can cause risk. Only use original parts or parts approved by the manufacturer.

The manufacturer takes no responsibility for damage as a result of using parts not released by, or approved by, the manufacturer.

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4.6 Coolant



The solution utilizes two types of coolant. The LT and HT cooling circuit uses the Glycol-based coolant Proviflow®, and the internal closed coolant loop of the FCwave™ uses GLYSANTIN® FC G20.

For more details, refer to the document "Material Safety Data Sheets".

During normal operation there should be no leakage of coolant. If a leakage is noted, Manufacturer must be informed.

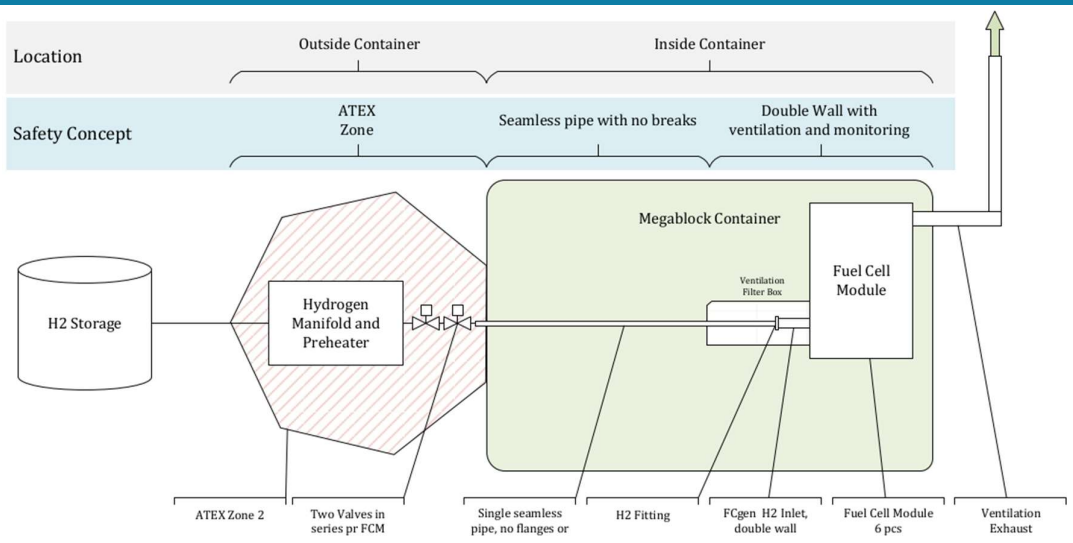
General rules are:

- Avoid contact with eyes and skin.
- Use protective gloves and tightly sealed googles.
- Avoid ingestion and inhalation of vapors.
- Spillage – do not allow to enter sewers/surface or ground water, absorb with a liquid–binding material, dilute with water.
- Disposal must be made according to official regulations.

4.7 Explosion safety

The hydrogen safety philosophy has several safety concepts, as indicated in Figure 2.

Figure 2: Hydrogen flow overview



Illustrative overview of hydrogen flow. See Hydrogen Safety Concept for more details.

Hydrogen is delivered to the hydrogen interface from a local hydrogen storage.

The area in which the interface, the hydrogen-manifold and -preheater, and hydrogen safety valves resides, is classified as an ATEX Zone 2. A hazardous mixture will not likely be present in normal operating conditions, and if so, only for a short period at a time. Electrical equipment in this zone is and shall conform to regulations and have the "EX" marking or similar. Detailed drawing of the hazard zone can be found in the General Arrangement. For more information regarding equipment installed in the zone, refer to the Equipment hazardous area certificate and schedule

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Respect the zone indicated, do not introduce any source of ignition.

There is no risk of hydrogen leakages inside the general space of the FC PowerGen Fuel Cell Container that can create an explosive atmosphere, due to the design of the feed pipes being seamless, one-piece-bends from outside of the container, routed through the container space, and connected the applicable Fuel Cell module.

The connection to a Fuel Cell Module (The H2 Fitting) is encapsulated within an extension of the Fuel Cell Modules Hydrogen Enclosure called the "Ventilation filter box", thus utilizing dilution and removal of any potential hydrogen with mechanical ventilation. Should leakages from this connection occur, the hydrogen detectors within the Fuel Cell Module will detect it and trigger a safe shutdown of that module and hydrogen supply.

The Ventilation system of the Fuel Cell Container creates a slight over-pressure to counteract ingress from particles and gas. As an additional precaution in case of hydrogen entering, the general space inside is equipped with hydrogen sensors. The position of these will detect any hydrogen entering or exiting the container through the ventilation system.

All safety-related triggers of the solution will shut off the hydrogen supply of either the affected system or the entire system.

4.7.1 Trace amount of H2

The process exhaust contains all biproducts from the fuel-cell stacks within the Fuel Cell Modules. The exhaust is a mixture of high-humidity, low-oxygen process air with trace amounts of hydrogen. The concentration of hydrogen will always be below 1%v, i.e. 25% of Lower Explosive Level (LEL), leading to a non-hazardous zone.

The source of the media in the Process Water Drain stems from the process exhaust. Thereby are also here found trace amount hydrogen which also are under 25% of LEL, leading to a non-hazardous zone. A hydrogen separator is fitted upstream to the process water drain and the trace amount of hydrogen are led through an exhaust to above the containers.

4.7.2 Working in the EX Zone

Personnel working in the EX-zone needs knowledge and skills as required by IEC 60079-14 and be approved as Operatives or Technicians on the EX-installation.



The defined EX zone is classified as Zone 2.

Only approved personnel are allowed to work in the ATEX Zone.



When working on systems containing hydrogen, refer to the correct procedures for Lock-out-tag-out. See Lockout Tagout document.

4.8 Fire safety

The Fuel Cell Modules have internal fire detection in the form of smoke detectors and linear heat detectors. If a Fuel Cell module detects fire, it will automatically perform a safe shutdown of itself and indicate an alarm.

If Smoke is detected inside the general space of the Fuel Cell Container or Converter Container, the entire system will perform a safe shutdown and indicate an alarm.

Should a fire occur, exit through the provided emergency exits.

There is no fire fighting equipment provided with the system.

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4.9 Electrical safety



The electrical system of the solution is designed in accordance with electrical and fuel cell codes to minimize electrical hazards. Electrical hazards may occur when the design is significantly compromised, typically through alteration, improper maintenance, or wear.

Dimensioning of cables and safety-equipment on the supplying and receiving end of electrical connections outside the solution must be done according to local legislation.

Select cabling and safety-equipment to the system that appropriately suits the application. Ensure to meet specifications of voltage, current, environmental temperature limits, chemical and mechanical resistance, and flexure requirements of the application. Avoid hazardous and unsafe situations that could result from condition such as, but not limited to:

- Improper grounding
- Handling electrical leads or devices with wet hands or on wet ground
- Frayed electrical leads
- Incorrect or improper connection of the terminal leads
- Short circuits
- Back-feed from energized normal and emergency power sources

Shutting down the solution during active Service and Maintenance may be necessary. Voltages may remain in the solution for a length of time. No activities are to be performed during this time as it presents a shock hazard.

Certain circumstances can lead to voltage persisting on the electrical systems. Always check for residual voltage before any activities. In some cases, it may require removal of hydrogen in the FCwave.

4.9.1 High DC Voltage Isolation Failures

Under normal circumstances, all high DC voltages are isolated from ground and the resistance is monitored. If isolation is lost on one high-voltage pole, a person working on the electrical system can sustain a fatal current-flow by touching the other voltage-pole and ground.

If two simultaneous faults occur and isolation is lost on both voltage-poles, a high voltage short circuit can occur resulting in extremely high currents/flash arcs. High currents can generate a large amount of heat which can subsequently damage electrical equipment and cause bodily harm.

Components inside the solution affects the resistance to ground, resulting in lower resistance over time.

Above-mentioned hazards are mitigated by the safety system of the solution. It actively monitors the resistance, warning if anything is to be reacted on, or shutting down the entire system in case of sustained resistance-drop or fault. Maintenance on the resistance-lowering-over-time-, and the monitoring-device(s) are crucial for the electrical safety of the system.

⚠ ELECTRICAL HAZARD	
	**If an isolation failure is detected and located in the MODULE, do not operate the fuel cell module until the root cause is determined and remedied.**

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4.9.2 Batteries

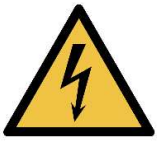


Batteries resides inside the system. Use applicable LOTO when working on system to avoid electrical hazards.

4.9.3 Converter Container access



The internals of the Converter Container are designed as an electrical cabinet (IP00), meaning that current-carrying conductors and terminals are exposed.

⚠ ELECTRICAL HAZARD	
	**HIGH VOLTAGE – 6.6 kV** **Danger of electrocution** **Authorized personnel only** **Keep clear and follow safety protocols** **Proper PPE required** **Failure to comply may result in serious injury or death**

Access is prohibited during operation. Opening the container doors activates the safety system, triggering emergency stop of the entire system. Residual voltages remain in certain components.

Entering this container requires prober de-energization and lockout tagout. Wait at least 10 minutes after de-energization before entering, and measure for residual voltages (<20VDC is safe).

4.10 Lock-out-tag-out (LOTO)

Ensure to use proper work-etiquette regarding LOTO on energy-containing systems, such as electrical supply, hydrogen, and batteries, when working on the system.

See Lockout Tagout document for procedures.

4.11 Heavy equipment

Some service and maintenance procedures require lifting of heavy equipment, such as an air-intake fan, top-module of an FCwave™, or an HT coolant pump motor.

Use of the monorail inside the fuel cell container, chain hoists, or forklifts are required, and safety precautions regarding these apply.

The Working Load Limit (WLL) of the monorail inside the Fuel Cell Container is 750kg.

4.12 Environmental conditions

Activities during rainy/snowy conditions should be avoided. If activities are performed during these conditions, the technician is responsible for ensuring that rain etc. does not enter the containers and electrical cabinets.

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Process exhaust contains water. During freezing conditions, snow and icicles may form.

Wear safety helmets under these conditions.

5.0 HMI - Service Interface

The system has a password-protected Service Interface, only accessible for authorized technicians.

The Service Interface can be accessed in three different ways:

1. Locally through the HMI touch screen located inside the Fuel Cell Container,
2. Locally with the use of a PC and a wired ethernet connection, to the secure internal network of the system, or
3. Remote access through the Secure Remote Access gateway.



Only trained and authorized personnel may access and use the Service Interface



Unauthorized accessing and usage of the Service Interface without proper training may result in serious injury

A default display showing main operating status is displayed when not in use as service interface.

6.0 Preparation for Maintenance

Technicians must examine the need for de-energization through means which is not within the scope of the system. Processes for de-energization of these shall be provided by whomever responsible.
Examples:

- Grid-connection switch-disconnector at customer end.
- Safety and/or isolation valve for Hydrogen supply.

Each service and maintenance tasks within the system may require varying de-energization of different sub-systems. User proper LOTO procedures as defined in the Lockout Tagout document.

An FCwave™ is placed in a "service state" prior to any de-energization of the hydrogen supply.

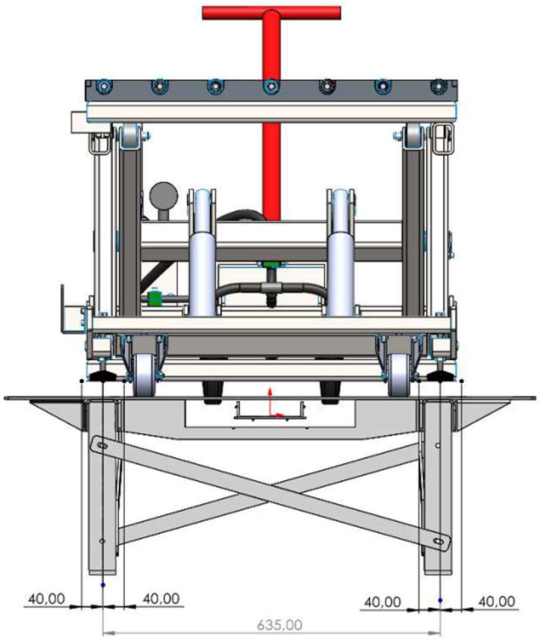
Service technicians must refer to the documents P&IDs, Electrical Single Line Diagram, and Electrical Cabinet Documentation for technical details of the system.

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6.1 FCwave™ Top-swap service tool

In order to perform a top-swap on an FCwave™, the service technician must use the applicable Service Cart Tool and follow the limits-of-use described below.

Figure 3: Placement of FCwave™ Service Cart Tool



Applicable service tool part number: 7000512

The flooring is designed only to temporarily carry the weight of the cart and top-module in a static state, transferring the weight to the legs of the floor through the leveling foots.

Ensure that the placement is correct (±40mm) – failing to do so will deform the flooring and may create a potential hazard for personnel.

The Service Cart Tool it is NOT intended to be moved on the wheels while carrying the top part of an FCwave™

To move a top-module of an FCwave™ inside the container, use an applicable hoist, mounted in the monorail.

For more details on the flooring, refer to the document Structural calculations - false floor.

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7.0 Preventative Maintenance - Fuel Cell Container

Figure 4: Fuel Cell Container – External overview



1: Main access door	4: HT drain valves
2: Service door	5: Hydrogen Heater
3: Air intakes	6: Hydrogen Interface

7.1 General External

7.1.1 Cleaning

The outside of the container may be cleaned using water and a nonabrasive cleaning agent.

Do not use high pressure cleaning.

During cleaning of Air intakes, the corresponding damper must manually be placed in closed position and disconnected. Reset to automatic after cleaning. The dampers can be actuated from the service interface.

7.1.2 Air dampers

The ventilation dampers must be able to operate unobstructed. Any material block or damage to damper blades must be corrected without unnecessary delay.

7.1.3 HT coolant drains

The HT coolant-drain valves at the bottom of the HT main pipes connecting the HT loop of the container to the HT cooling platform must be closed.

In case of leakage, immediately correct and check level of coolant.

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7.1.4 Access areas

The areas in front of the main door, the service door, and the cooling platform service area should be kept clean and free from obstacles.

7.1.5 Process water drain

The process water drain is directed to a designated drainage system of the local site.

It should be checked at every maintenance period that the drain is unobstructed.

The process drain is equipped with an exhaust and a heat trace that protects the drain against freezing. Inspection is performed according to the Maintenance Plan.

Process water is DI water and is not suitable as drinking water.

7.1.6 Process-, ventilation, and drain exhausts.

Each FCwave unit has a set of exhausts: process air and ventilation.

The drain has an exhaust.

It should be checked at every maintenance period that the exhausts are unobstructed.

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7.2 EX-zone

De-energization of electrical components for maintenance must be done, ensuring that no ignition source ever exists in the EX-zone.

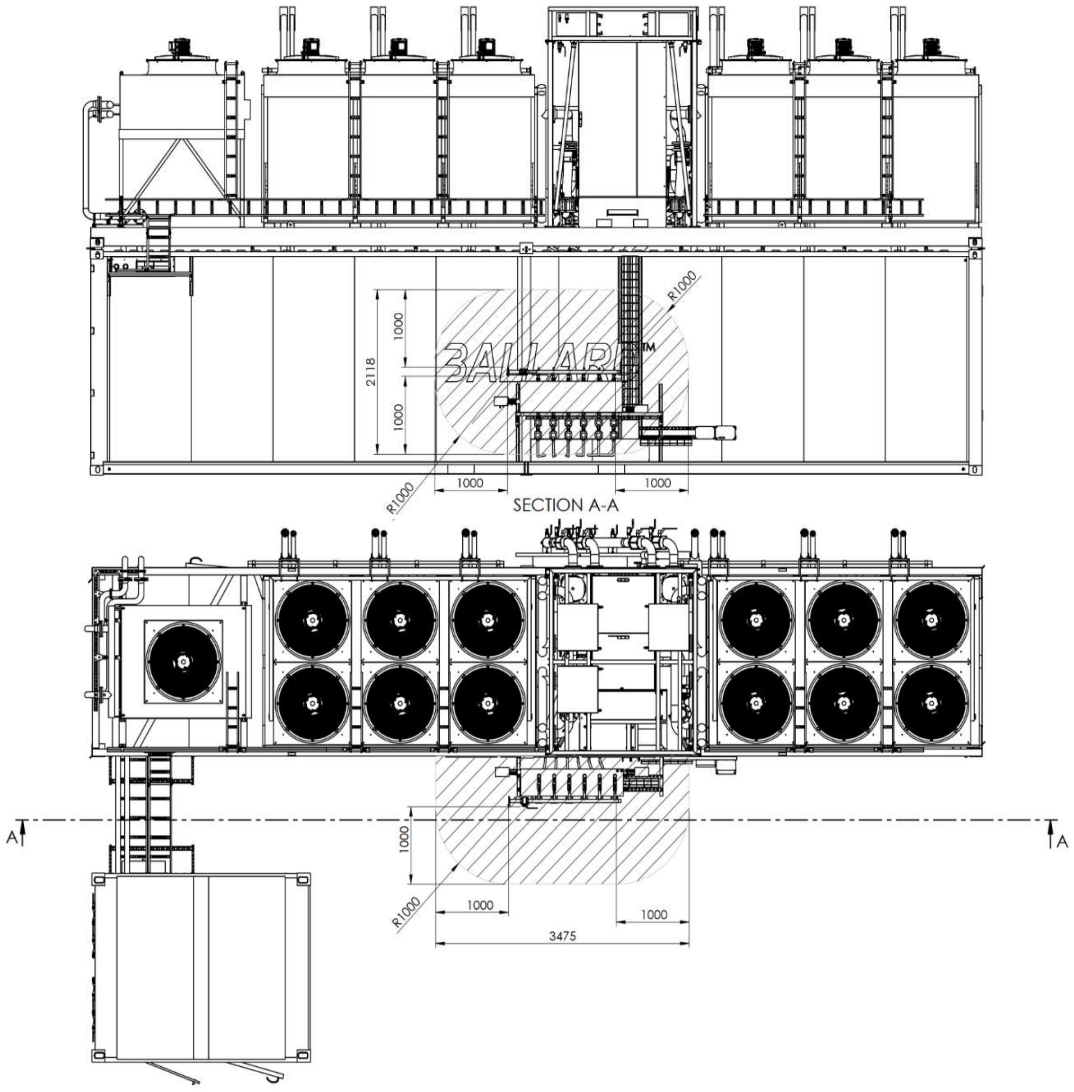


The defined EX zone is classified as Zone 2.

Only approved personnel are allowed to work in the ATEX Zone.



Figure 5: EZ-zone illustration



For detailed version, refer to the General Arrangement

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7.2.1 Hydrogen heater

During low ambient temperature, the hydrogen is heated to the hydrogen heater. The heater is filled with coolant and are heated using electrical heating elements.

The surface of the heater may reach up to 45°C.



If the Hydrogen Heater has run recently, wait for it to cool down before touching it and components mounted.

The following components of the Hydrogen Heater have no defined service/maintenance tasks defined by their documentation.

- Pressure sensor
- Temperature sensor
- Cables to sensors
- Cables to heating elements
- Cable glands on JEVI D-8640 heating elements
- Cable glands on Solenoid Shut-off valve (H2)
- Sensor EX barrier
- General Hy-lok fittings

  It is recommended that visual inspection on above-mentioned components is done.

7.2.1.1 Hydrogen Heater cooling media

The coolant level is monitored. In case of low level, it must be topped up.

The Hydrogen heater must have the coolant freeze-protection checked with the use of a refractometer regularly and changed as needed.

Coolant is 50/50% mixture of demineralized water and Proviflow Neo, which is an Ethylene-glycol based. Can be purchased as pre-mixed.

Criteria: minimum freezing point of -30°C

7.2.1.2 Level sensor – IFM LMT01A

Refer to Manufacturers (IFM) Operating Instructions – section 9.

- De-energize supply
- Check sensor tip for deposits and damage. Clean if badly soiled. In case of damage, replace the unit – the unit cannot be repaired.
- When reinstalling, carefully clean the probe neck and the installation slot, especially the sealing surface, with appropriate methods to ensure that the unit is resistant to ingress and without dead space.
- Re-energize supply.

7.2.1.3 Heating element - JEVI D-8640

Refer to Manufacturer's (JEVI) Installation, Operation and maintenance instructions, section 4.0

Maintenance free, however after 1 year of operation:

- De-energize supply (=LA01+UC30-FC41…42)
- Check the thermostat for damage

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- Check connections inside junction box
- verify correct connections and re-assemble
- Re-energize supply

If no heating is done when needed, check and press the manual reset button.

7.2.2 H2 Solenoid Shut-off valve – Emerson ACSO

Check for excessive wear – leakage tests

- Externally

  Potential leakage areas: Pipe connections (Hy-lok) and valve stem.

  Hy-lok connections have low probability of leakage. If leakage occur, refer to components manual for replacement.

  If leakage from valve stem, rebuild with manufacturer kit or replace component.
- Inline

  If inline leakage occurs, rebuild with manufacturer kit or replace component.

Leakage test:

- Close valve(s) on designated H2 line
- Lower pressure downstream
- Monitor pressure downstream for a set period
- Search for external leakages with applicable outdoor-use leakage detector.

7.2.3 Manual isolation valve – Hy-lok 110 Ball Valve

Refer to Manufacturers (Hy-lok) Instruction manual for maintenance.

Leakage test – Stem:

In case of stem leakage, tighten the Flange Nut. If the leakage remains after tightening, check damage to the stem, outer package and inner package. Replace parts or component(s) as needed,

Leakage test – Inline:

If the leakage happens inside the valve, ensure whether the valve is in fully closed condition. If the reason of leakage is seat damage, replace the seat or the component.

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7.3 Access



Access is restricted to authorized personnel only

7.3.1 Main access door

The door on the container side is the main entrance to the interior of the Fuel Cell Container. The door is locked and should only be unlocked by authorized personnel during service.

It is possible to unlock the door and enter the container while it is in full or partial operation.

In this case the door may not be kept open for a longer period, as this will affect the internal ventilation system. **Note**: The ventilation creates a slight overpressure inside the container.

Generally, the door should be closed to keep a clean environment inside the container.

7.3.2 Service door

The service door at the end of the container is intended for special service cases and should otherwise be kept closed.

The door can in any case be opened from inside and functions as an emergency exit.



Service personnel must unlock this service door when any activities are performed inside the container, to enable any first responders to gain access if needed.

7.3.3 Container doors

The standard container doors are not intended for use and should always be locked.

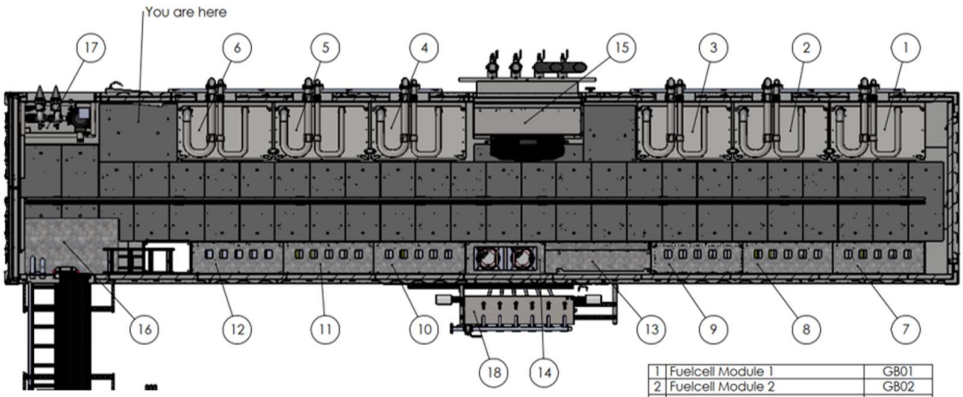


Before leaving the site check that all doors are safely locked.

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7.4 Internal

Figure 6: Fuel Cell Container - Internal overview



1	Fuelcell Module 1	GB01
2	Fuelcell Module 2	GB02
3	Fuelcell Module 3	GB03
4	Fuelcell Module 4	GB04
5	Fuelcell Module 5	GB05
6	Fuelcell Module 6	GB06
7	Fuelcell DC/DC Cabinet 1	UC01
8	Fuelcell DC/DC Cabinet 2	UC02
9	Fuelcell DC/DC Cabinet 3	UC03
10	Fuelcell DC/DC Cabinet 4	UC04
11	Fuelcell DC/DC Cabinet 5	UC05
12	Fuelcell DC/DC Cabinet 6	UC06
13	Controle Cabinet	UC20
14	Internal Container Ventilation	UC07
15	Container Ventilation	
16	AUX Transformer	TA03
17	LT Pump Rack	GP11
18	H2 Heater	EB01

Indicative illustration of the internals of the Fuel Cell Container

7.4.1 General

The interior should be kept clean and walking space unobstructed.

The floor plates are secured by screws and should always be secured unless service is in progress.

When working in the area below the floor, it is recommended to use gloves.



When the system is in operation use hearing protection.

If the system is locked to prevent starting, having hearing protection available is only recommended.



When working in the container, make sure that there is free access to an emergency exit door, and unlock the doors to allow for rescue personnel to enter the container through the emergency doors.



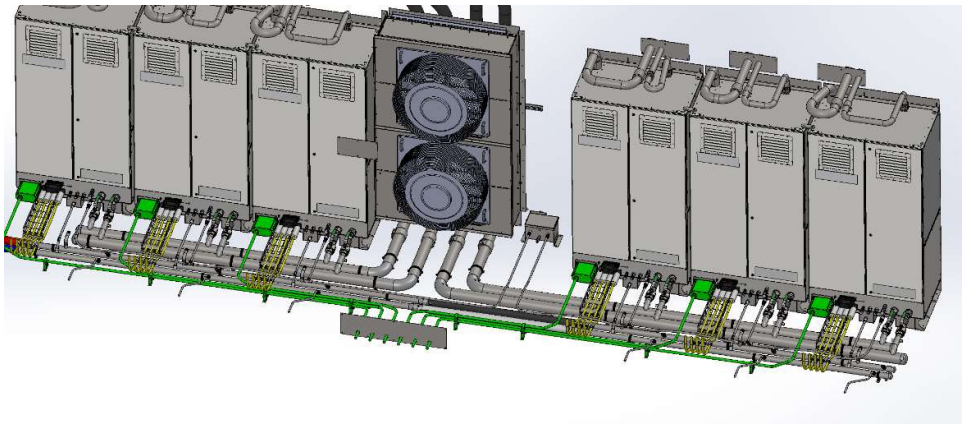
The container interior is equipped with overhead light sources. Use additional light where appropriate to avoid errors.

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7.4.2 Hydrogen piping

The hydrogen-piping runs as seamless feed pipes from the outside of the container and into Ventilation Filter Box where it is connected to the Fuel cell module.

Figure 7: Hydrogen piping



The interior hydrogen supply system is located below the floor.

Refer to P&IDs document for more details.

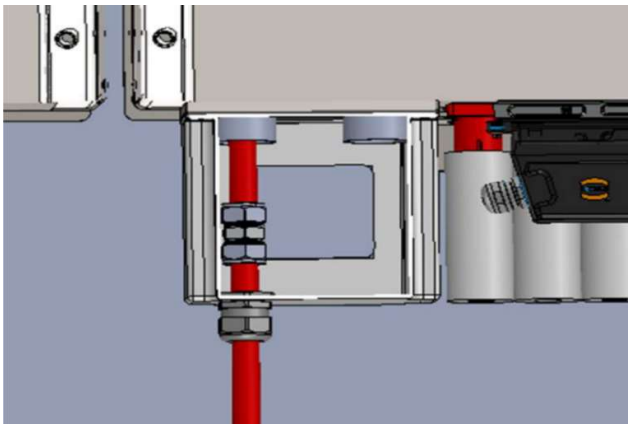
Special procedure must be followed to purge hydrogen in the piping downstream from isolation valve

7.4.3 Fuel cell hydrogen connection (ventilation filter box)

The ventilation filter box ensures that the supply-connection is well ventilated during normal operation, ensuring dilution and removal of any, highly unlikely, hydrogen leakage.

These connections must be checked with a hydrogen sniffer, and the filter of the ventilation filter box changed as defined by the Maintenance Plan.

Figure 8: Ventilation filter box



Top-view cut-off illustration of ventilation filter box. The filter is fitted to the bottom opening.

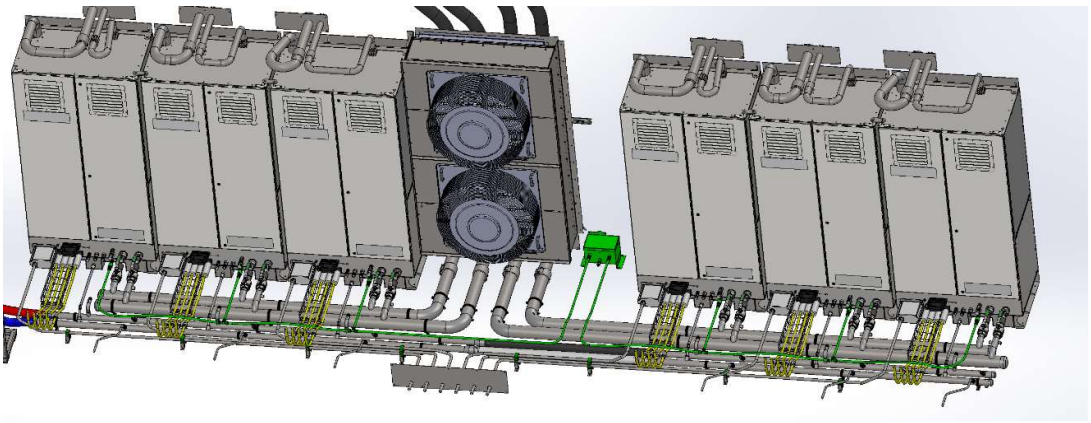
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7.4.4 Fuel cell process water drain

The fuel cell process water drain system collects process water from the Fuel Cell Modules (DI-water from the chemical reaction). This is led to a separator tank where gaseous matter is separated from the media. The gaseous matter is led to an exhaust, and the liquid matter are led to the exterior drain described in section 7.1.5.

Refer to P&IDs document for more details.

Figure 9: Process water drain system



Indicative illustration of piping and tank – layout/design my vary.

The separator tank is placed below the floor next to the main air-intake.

A heater wire is mounted to the exhaust and drain interface, ensuring that the water does not freeze. Inspect this system as defined by the Maintenance Plan.

7.4.5 Fuel cells

The service scheme for the FCwave is not covered in this document. Prior to service activity on the FCwave, the person must complete Ballard training relevant for the service planned. Service and safety instructions will be made available as part of the training.

Access to the interior of the FCwave units is only permitted for authorized personnel - see 2.3.2

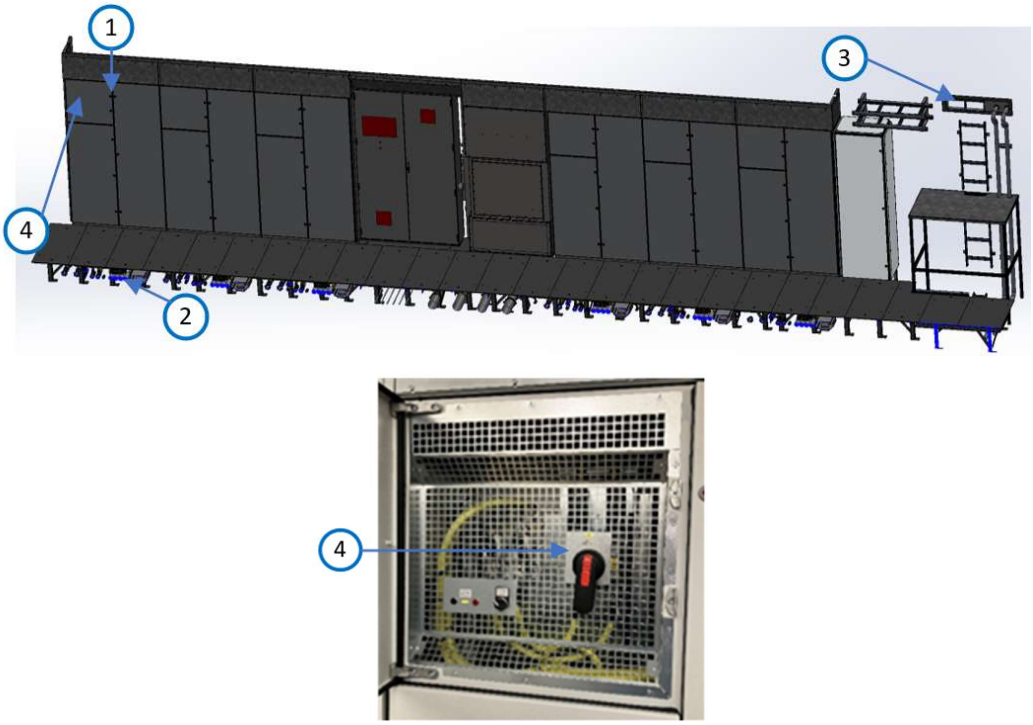
For details on service and maintenance tasks, refer to FCwave – Service and Maintenance Manual and the attached Maintenance plan for the FCwave.

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7.4.6 Electrical DC system

The power system is based on 750 VDC.
Special safety procedures must be followed when working on the system.
Do not open DC cabinets without following proper procedure

Figure 10: DC system



1: DC cabinet (1 of 6)
2: DC fuel cell cable
3: DC out to Converter Container
4: DC cabinet breaker

Each DC cabinet is equipped with a breaker behind the top left door. The breaker is used to isolate the cabinet and corresponding Fuel Cell Module from the DC link.

Proper procedure must be followed when dis- and re-connecting a DC cabinet, failure to do so may result in damage or injury.

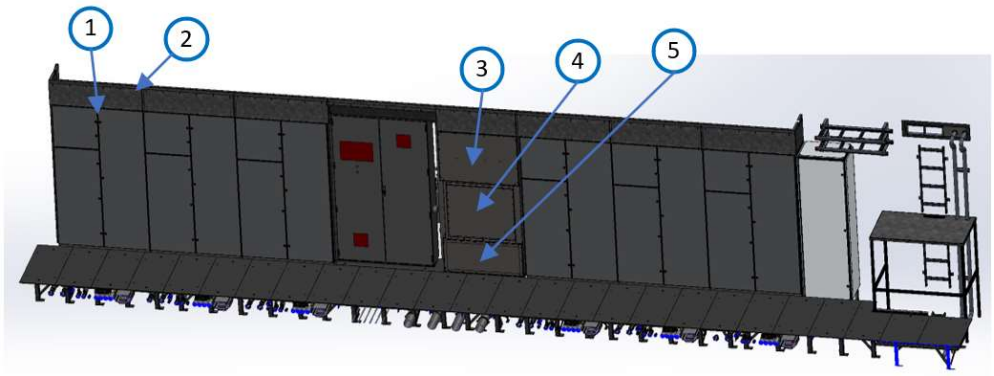
A yearly inspection of each DC cabinet must be done, including checking for leakages of coolant and a thermographic inspection of electrical components and connections.

Any time access to DC areas is made, ensure cleanliness.

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7.4.7 Internal ventilation

Figure 11: Internal ventilation



1: DC/DC cabinet 2: Ventilation/DC-cable duct	3: Ventilation fan box 4: Heating element box 5: Ventilation outlet

The internal ventilation system is removing heat from the power electronics and adding room heating in case of low temperature.

The circulation fan is placed in the central unit (3) together with a heater (4). It pulls air from below the floor, through the DC cabinets (1). Heated air exits at the outlet by the floor (5).

Each of the cabinets that the air is pulled through has a manual air-restrictor in the top, which is mounted in a fixed position, equalizing the flow through all ventilated cabinets. The settings of these are not to be changed.

There are no filters in the system.

Refer to P&IDs document for more details.



Do not open the ventilation duct unless the entire system is shut down and deenergized.

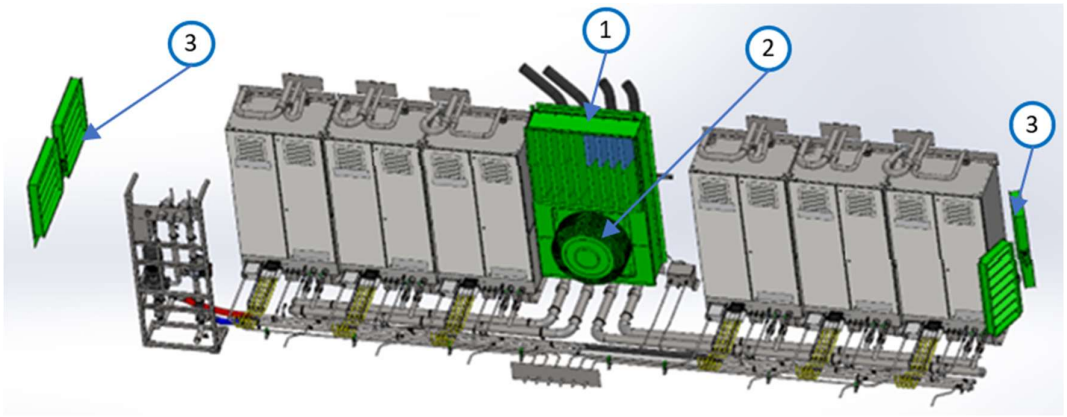
The DC cables are inside the conduit and there is access to the DC cabinets from the duct.

The heating element box must be cleaned and undergo a thermographic inspection of electrical power connections.

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7.4.8 External ventilation

Figure 12: Indicative illustration of external ventilation



1: Inlet filters
2: Main intake fans
3: Ventilation outlet with damper
Layout may vary

The external ventilation system is dual functioning, using external air to remove heat from the inside and providing air for the fuel cell process. Air flow is based on multiple parameters and controlled by fan speed and damper position.

The external ventilation is made to ensure a clean environment inside the container by filtering all incoming air and maintaining a slight overpressure inside the container.

Refer to P&IDs for more details.

Opening the doors of the container disturbs the air balance in the container. When doors are open, the fans will run in a locked base, unregulated setting – do not leave doors open unnecessarily.

The pressure-drop across the main filters is monitored to ensure proper function. The main filters replacement schedule is defined by the Maintenance Plan.

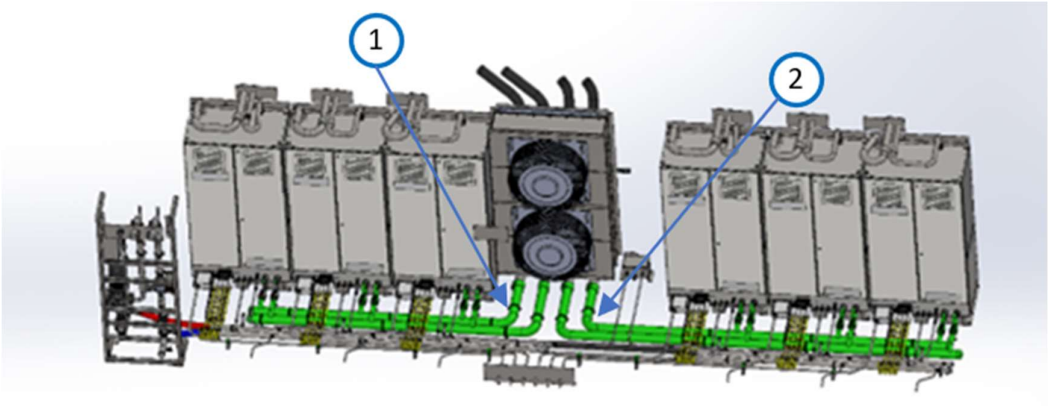
The service schedule for the fans of the intake is defined by the Maintenance Plan.

The dampers should be able to operate unobstructed. Any material block or damage to damper blades must be corrected without delay.

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7.4.9 HT Cooling systems

Figure 13: Indicative illustration of HT cooling system



1: HT cooling manifold FC 4, 5 & 6
2: HT cooling manifold FC 1, 2 & 3
Layout may vary

The 2 HT cooling systems are cooling the fuel cell stacks for FC1,2,3 and FC4,5,6 respectively, at approximately 60°C.

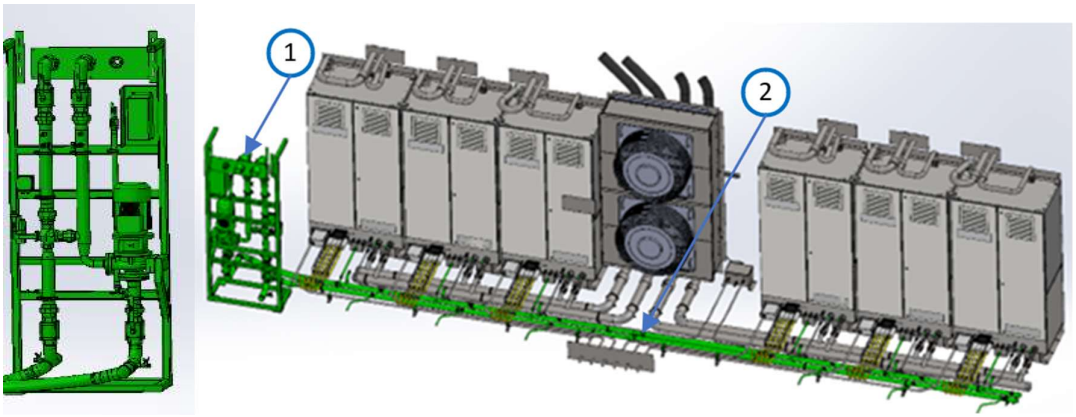
Details of the cooling media can be found in the document Material Safety Data Sheets.

There are no serviceable parts of the HT cooling system inside the container, but a visual inspection for leakages must be conducted.

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7.4.10 LT Cooling systems

Figure 14: Indicative illustration of LT cooling system



1: LT cooling pump rack
2: LT cooling manifold
Layout may vary

The LT cooling systems provides cooling for power electronics at approximately 45°C.
Refer to P&IDs and document for more details.
Details of the cooling media can be found in the document Material Safety Data Sheets.
The LT pump must be serviced as defined by the Maintenance Plan.
The LT Coolant strainer must be inspected and cleaned as defined by the Maintenance Plan.
Testing of the quality of the freeze-protection in the coolant.

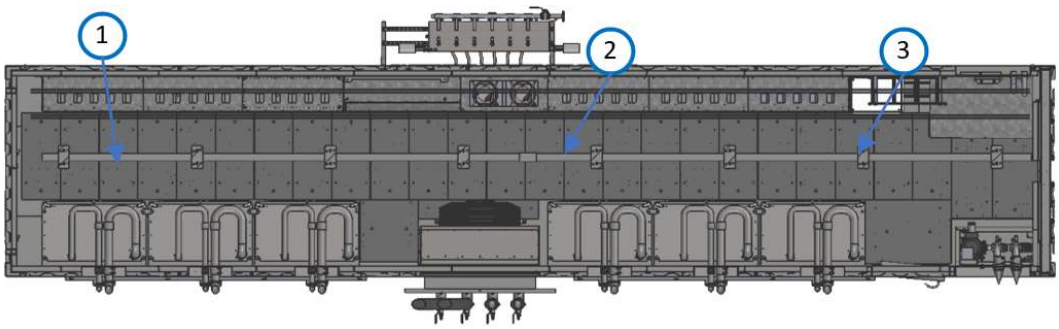
7.4.11 UPS

The container houses several 24VDC UPS modules. These are located under the floor.
The functionality of these, and the battery health must be checked.

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7.4.12 Container safety system

Figure 15: Safety sensors location



1, 2 and 3: H2 sensor & smoke detector

The container interior is equipped with 3 sets of safety sensors, each consisting of an H2 sensor and a smoke detector.

The sensors are integrated in the container safety system together with the FCwave safety signals, emergency stop, and electrical safety.

Figure 16: Safety sensors



H2 detection and smoke detection

The function of the sensors is tested as defined by the Maintenance Plan.

The H2 sensor must be calibrated as defined and change of sensor must be done because of degradation.

Functionality test on the emergency stops internally and externally to the system must be conducted.

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8.0 Preventative Maintenance – Converter Container

Figure 17: Converter Container – external overview



1: Access door	4: Air exhaust
2: Main breaker access door	5: Grid Interface
3: Control cabinet access door	6: Air Intake

The Converter Container has the main output power electronics and transformer inside. The interior is not a workplace, and it should only be accessed as needed for specific services.

8.1 External

8.1.1 Cleaning

The outside of the container may be cleaned using water and a nonabrasive cleaning agent.

Do not use high pressure cleaning.

During cleaning of Air intakes, the corresponding damper must manually be places in closed position and disconnected. Reset to automatic after cleaning. The dampers can be actuated from the service interface.

8.1.2 Air dampers

The ventilation dampers must be able to operate unobstructed. Any material block or damage to damper blades must be corrected without unnecessary delay.

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8.2 Access

The service door at the end of the container is intended for special service cases and should otherwise be kept closed.



Access to the internals is for authorized personnel only.
Never force entry.



Proper procedures for lock-out-tag-out must be performed, prior to entering.
See Lockout Tagout document.



Before leaving the site check that all doors are safely locked.

8.3 Internal

8.3.1 General

The interior should be kept clean and walking space unobstructed.



The UPS actively supply power to the control cabinet when the AC supply is disconnected.



Never work inside the container without a colleague.

Only firefighters should open the doors in case of fire.

8.4 Ventilation

The ventilation is made to ensure proper temperature and a clean environment inside the container by filtering all incoming air and maintaining a slight overpressure inside the container.

The pressure-drop across the main filters is monitored to ensure proper function. The main filters replacement schedule is defined by the Maintenance Plan.

The service schedule for the fans of the intake is defined by the Maintenance Plan.

The dampers should be able to operate unobstructed. Any material block or damage to damper blades must be corrected without delay.

The heating elements of the container heater must be inspected and cleaned.

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8.5 Power components

The internal DC bus is supplied by the incoming DC from the Fuel Cell Container.

The power from the Fuel Cell Container is converted to 400 V AC and connects to the Main breaker (grid connection). Components include DCAC converter with filter, transformer 400VAC to 6,6 kVAC, main breaker and connecting busbars.

Thermographic inspection of power electronics, connections, and applicable cabinets must be performed.

8.6 LT Cooling

The LT cooling system provides cooling of power electronics at approximately 45°C.

Refer to P&IDs and Material Safety Data Sheets document for more details.

The connections of the LT cooling system must be inspected for leakages.

8.7 UPS

The container houses several 24VDC UPS modules. The functionality of these, and the battery health must be checked.

8.8 Container safety sensors

Figure 18: Sensors



Smoke detector & temperature sensor

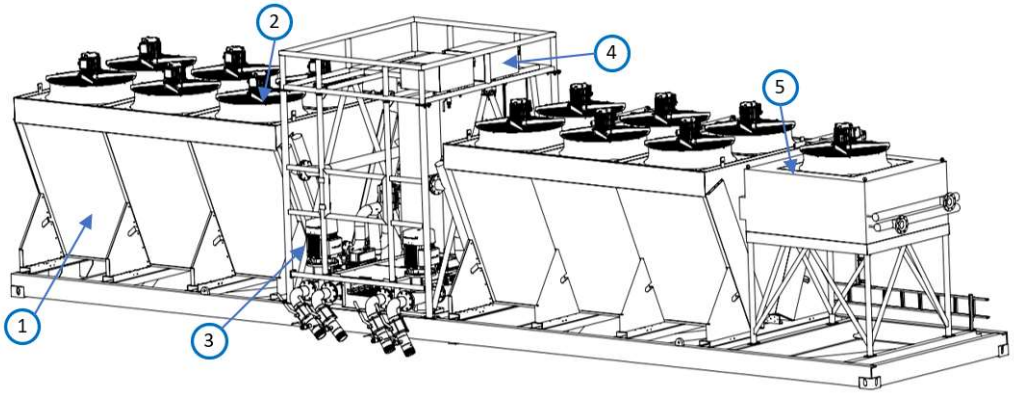
The container interior is monitored for smoke, has a safe-lock and door safety switches, one on each container door pair.

The sensors are integrated in the container safety system.

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9.0 Preventative Maintenance - Cooling Platform

Figure 19: Cooling platform - Overview



1: HT Cooler 2: Cooler fan 3: HT pump	4: Header Tank 5: LT Cooler

The Cooler platform has 2 individual HT cooling systems and the cooler for the LT Cooling system.

The HT Cooling systems are identical, each with a dry cooler, header tank, pump, valves, and sensors.

Each of the three cooling system is designed to allow for operation up to external temperature of 45°C. The systems are without active cooling, and it is therefore important that the coolers are kept in good operating condition.

There must be regular inspection of coolers at each service visit. The coolers must be kept clean and free from material blocking the airflow.

There is minimum a yearly cleaning and inspection of the coolers.

Cleaning of coolers, access to fans etc. may require using a ladder, lift, scaffolding or similar - Availability is customer responsibility, or as agreed upon.

Rules for working in height and fall arrest equipment applies.

Pumps, sensors, and valves can generally be serviced from the work platform. The platform is designed to be reachable by ladder and has a safety cave. Working inside the cave with the gate closed can be done without fall arrest equipment.

The HT pumps must be visually checked for leakages and serviced as defined by the Maintenance Plan.

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The cooling system contains Glycol.
See Material Safety Data Sheets for details.
Avoid spillage, use gloves and eye protection.

The coolant levels are monitored by level switches in the header tanks. In case of low coolant level, it must be topped up. The function of the level switches must be verified, defined by the Maintenance Plan.

The coolant must be checked yearly to secure proper freezing protection.

If for service or other reasons one of the cooling systems must be emptied and refilled, procedure must be followed, ensuring that the system is de-aeriated.

The Control Cabinet of the Cooling platform contains a UPS that must be tested as defined by the Maintenance Plan.

Fans on the coolers must be visually inspected and cleaned.

HT Fan Drive Cabinet Chiller shall have checked/cleaned/replaced the air-intake filter, cleaned the condensate drain trap and recharged refrigerant as needed.

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10.0 Troubleshooting

The system allows for remote monitoring where warnings and alarms are available. The following troubleshooting processes should be done by trained personnel. Refer to Cause and Effects Chart.

10.1 Safety system

Safety trip on an FCwave, Hydrogen safety valve override, Power converter Safe Torque Off (STO) or motor drive STO:

- Check internal and integrator-provided emergency stop buttons
- Check for hydrogen detection
- Check for fire detection

10.2 Hydrogen

If the hydrogen valves by the hydrogen heater are unexpectedly closed:

- Check internal emergency stop buttons
- Check for hydrogen detection
- Check for fire detection
- Check for DCAC Converter trip
- Check for LT Cooling system loss
- Check for ventilation failure
- Check the process water drain for blockage
- Check for communication failure to integrator
- Check for hydrogen supply and signal

10.3 FCwave

Single module has stopped:

- Check for FCwave internal alarm
- Check for applicable DCDC's trip

Multiple modules have stopped:

- Check for HT Cooling system loss

All modules have stopped:

- Check for DCAC converter trip
- Check for LT Cooling system loss
- Check for ventilation failure
- Check the process water drain for blockage
- Check for communication failure to integrator
- Check for hydrogen supply and signal

Single module Derate:

- Check for FCwave internal warnings

Multiple modules Derate:

- Check for HT cooling system loss

All modules Derate:

- Check for LT Cooling system loss
- Check for Ventilation Derate

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10.4 Power converters

Power converter derates:

- Check LT Cooling system Derate
- Check ventilation derate (Some power converters are air-cooled)

Power converter stop:

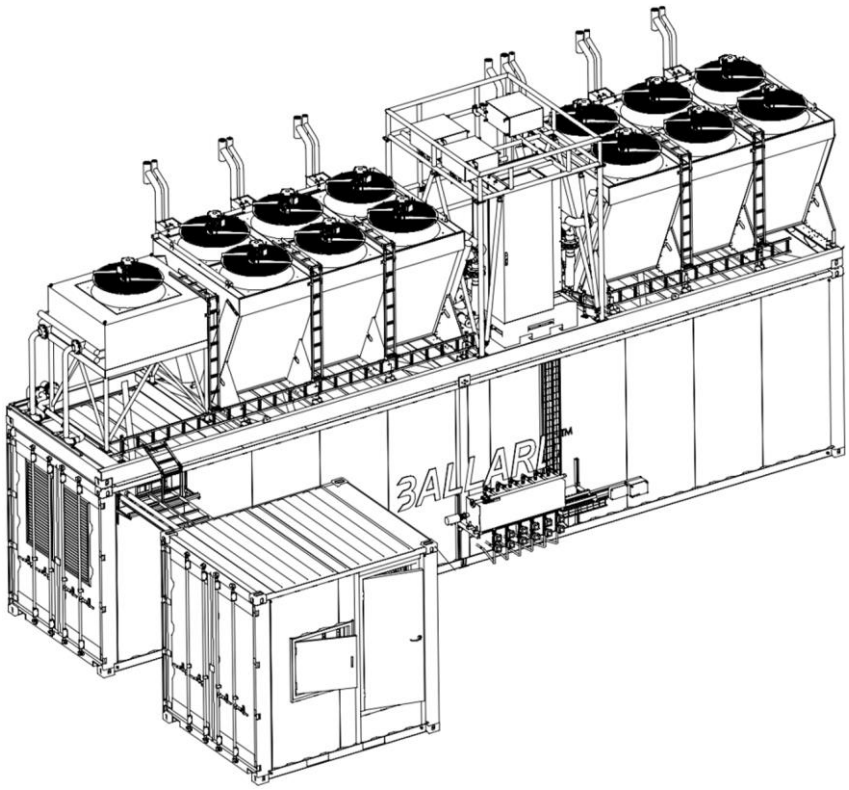
- Check DCDC converter trip
- Check DCAC converter trip
- Check for LT Cooling system loss
- Check ventilation derate (Some power converters are air-cooled)
- Check for communication failure to integrator

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FC PowerGen 1000kW

Part no.:	601456B-7002362
Configuration:	40ft Fuel Cell Container w. 6 FCwave's 10ft Converter Container, 6,6 kVAC

Maintenance Plan



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1.0 Fuel Cell Container

Table 1-1: Fuel Cell Container – Preventive Maintenance schedule

Task	Usage-based[1] Hours	Time-based Months/years	Comment
General			
Cleaning	Each visit	6 mths	Ensure that the container is clean and that the walk-area inside and outside is clear of obstacles
Hydrogen			
Check Hydrogen piping		1 yr	Sniffer-test for leakages (FCM interface, hydrogen Interface, hydrogen heater)
Check Hydrogen Heater coolant level and level sensor		6 mths	Functionally test of level senor, check coolant level, add if necessary
Test Hydrogen Heater coolant quality		1 yr	Check Freeze protection quality with refractometer
Check Hydrogen Heater heating elements		1 yr	Functionality check of Hydrogen heater
Leakage test – H2 Solenoid shut-off valve		1 yr	External/inline testing.
Leakage test – Manual isolation valve		1 yr	External/inline testing.
Process Drain			
Check Process drain heat trace		6 mths	Check functionality with thermography
Check Process drain catch-tank level switch		1 yr	Functionality check of Level switch
Cooling			
Check HT cooling system		6 mths	Visual check for leakages
Check LT cooling system		6 mths	Visual check for leakages
Check LT coolant strainer		6 mths	Visual check for cleanliness. Clean if dirty
LT Coolant pump and motor		6 mths	Visual check for leakages. Clean if dirty.
Test LT Coolant quality		1 yr	Check Freeze protection quality with refractometer
Ventilation			
Check ventilation dampers (Louvres)	Each visit	6 mths	Functionality check. Obstruction and/or damage must be corrected. Clean if dirty
Check container heater cleanliness		1 yr	Clean if dirty
Check container Air-intake-fan		6 mths	Visual inspection for damage, dust, and grime
Change container Air-intake filter		6 mths	Replace
Change Ventilation Filter Box (Fuel Cell Module)		6 mths	Replace
Electrical			

[1] Service interval, whichever comes first

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Table 1-1: Fuel Cell Container – Preventive Maintenance schedule			
Thermography inspection		1 yr	Of power electronics, cabinets, and heating
Check UPS		1 yr	Functionality test and battery health
Clean DC/DC cabinets		1 yr	Clean if dirty
Safety system			
Check smoke detectors		1 yr	Functionality test
Calibrate Hydrogen sensor		1 yr	Use test-gas
Life-check Hydrogen sensor		6 mths	Check sensor vitality
Change Hydrogen sensor		TBD[2]	Replace Hydrogen sensor due to degradation
Emergency stop (internals and externals)		1 yr	Functionality test
Test RCD's		6 mths	Functionality test with applicable multimeter

[2] Depends on environmental conditions, and are a result of the sensor vitality test

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2.0 Converter Container

Table 2-1: Converter Container – Preventive Maintenance schedule

Task	Usage-based[1] Hours	Time-based Months/years	Comment
General			
Cleaning	Each visit	6 mths	Ensure that the container exterior and interior are clean, and that the walk-area inside and outside is clear of obstacles
Cooling			
Check LT cooling system		6 mths	Check for leakages
Ventilation			
Check ventilation dampers (Louvres)	Each visit	6 mths	Functionality check. Obstruction and/or damage must be corrected. Clean if dirty
Check container heater cleanliness		1 yr	Inspect. Clean if dirty
Check container Air-intake-fan		1 yr	Visual inspection for damage, dust, and grime
Change container Air-intake filter		6 mths	Replace
Electrical			
Thermographic inspection		1 yr	Of power electronics, cabinets, and heating
Check UPS		1 yr	Functionality test and battery health
Safety system			
Check smoke detectors		1 yr	Functionality test
Check Safety-lock		1 yr	Functionality test
Check Door safety switches		1 yr	Functionality test
Test RCD's		6 mths	Functionality test with applicable multimeter

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3.0 Cooling Platform

Table 3-1: Cooling Platform – Preventive Maintenance schedule

Task	Usage-based[1] Hours	Time-based Months/years	Comment
Cooling			
Check cooler cleanliness	Each visit	6 mths	Clean if dirty (Pressure wash as per cooler manual)
Check HT coolant level		6 mths	Add if necessary. If excessive amount missing, search for leakages.
Test HT Coolant quality		1 yr	Check Freeze protection quality with refractometer
Check LT coolant level		6 mths	Add if necessary. If excessive amount missing, search for leakages.
Check Header-tank(s) level switch		1 yr	Functionality check of Level switch
Check cooler fan(s)		1 yr	Visual inspection for damage, dust, and grime
Check HT coolant pump(s)		6 mths	Visual check for leakages. Clean if dirty.
Main inspection HT Coolant pump(s)	16000h	2 yr	Inspect bearing temperature, noise, cracks, alignment, bolt/screws tightness, electrical connections, winding isolation resistance, bearing condition
Check HT Fan Drive Cabinet Chiller air-intake filter		1 yr[3]	Clean with warm water from exhaust side to intake side and let et dry or replace.
Check HT Fan Drive Cabinet Chiller condensate drain trap			Clean by pouring soapy water into the face of evaporator coil. Alternatively, locate drain and blow compressed air.
Fan Drive Cabinet Chiller refrigerant recharging			Standard Discharge/recharge procedure for R134A
Electrical			
Check UPS		Yearly	Functionality test and battery health
Test RCD's		6 mths	Functionality test with applicable multimeter

[3] Depends on environmental conditions

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5.1.4 Maintenance Plan – MAN001-C

It is required to follow maintenance plan to ensure trouble-free operation during the lifetime of FCwave module.

The maintenance tasks for the FCwave module are listed in the Table 5-1. Refer to the Customer Portal (see section 1.1) for the latest revision.

Make sure that all electrical connections are disconnected before performing any maintenance activity on the FCwave module.

Maintenance Plan, FCwave 200kW	Document ID: MAN001-C			Revision: 0
	*Interval			
Task	Hours	Month(s)	References	Comments
Check coolant level indicator	250	1	Refer to section 5.4.4	Inspect the level between minimum and maximum
Check ventilation inlet flow switch	1000	3	Refer to section 5.5.4	Check if ventilation stops to function at set level alarm.
Check differential pressure safety switch	1000	3	Refer to section 5.5.6	The safety shut down system must activate in absence of negative pressure in H_2 enclosure.
Check fuel cell module BOP components	N/A	3	Refer to section 5.6.1	Coordinate this while performing other inspections or service is performed
Check external harnesses and electrical components	N/A	3	Refer to section 5.6.2	Check all external harnesses and electrical components for signs of damage or corrosion
Check for coolant leaks	1500	3	Refer to section 5.4.1	Check external coolant hoses and module for signs of coolant leaks
Check stack coolant conductivity	1500	3	Refer to section 5.4.2	Replace DI filter (resin cartridge) if conductivity exceeds specification of <5mS/cm.

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Maintenance Plan, FCwave 200kW	Document ID: MAN001-C			Revision: 0
	*Interval			
Task	Hours	Month(s)	References	Comments
		Note: Depending on the integration layout, more frequent servicing may be required. All integrators must include a working ground fault monitoring system as a part of integration, and shutdown the system if grounding resistance is too low.		
Check smoke detector functionality	1000	3	Refer to section 5.5.7	This is a mandatory service activity
Check ground fault monitor functionality	N/A	3	Refer to section 5.6.3	If used, this is a mandatory service activity
Check calibration of hydrogen sensor	1000	3	Refer to section 5.5.2	This is a mandatory service activity, record sensor readings. Replace if necessary
Check module ventilation air intake filter and fans	1000	3	Refer to section 5.7.1 and section 5.5.9	Check module ventilation air intake filter condition and fan functionality, replace if necessary
Check coolant particulate filter (Wedge wire screen)	6000	Every 1 year	Refer to section 5.4.3	Check filter (wedge wire screen) and gasket at the main module inlet. Clean and install if needed. Replace if necessary.
Check Linear heat detector functionality	N/A	6	Refer to section 5.5.1	-
Check LV Electronic circuit breaker	N/A	N/A	Refer to section 5.6.13	In case of failure or misreading in the system, it is recommended to replace
Replace Purge valve	N/A	Every 5 years	Refer to section 5.2.1	Check for durability issues and quality, replace if necessary
Replace HRB	5000	Every 1 year	Refer to section 5.2.2	Check for leak issues on shaft sealing, replace if necessary

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Maintenance Plan, FCwave 200kW	Document ID: MAN001-C			Revision: 0
	*Interval			
Task	Hours	Month(s)	References	Comments
Replace HRB spider coupling	10000	Every 2 years	Refer to section 5.2.2	Inspect for wear, replace if necessary
Replace HRB Motor bearings	20000	Every 5 years	Refer to section 5.2.2	Check for vibration levels depending on RPM of the motor
Replace Hydrogen Valve block	N/A	Every 5 years	Refer to section 5.2.3	Check for durability issues and quality, replace if necessary
Check of Safety valve in Valve block	N/A	Every 5 years	Refer to section 5.2.3	*Under construction*
Replace process air filter/mass flow meter	10000	Every 2 years	Refer to section 5.3.1	Check for durability issues and quality, replace if necessary
Replace process air valves	N/A	Every 5 years	Refer to section 5.3.2	Check for durability issues and quality, replace if necessary
Replace Humidifier (x3) unit	7000	Every 2 years	Refer to section 5.3.3	Check for durability issues membrane quality, replace if necessary
Replace Aftercooler assembly	N/A	Every 2 years	Refer to section 5.3.4	Check for durability issues and quality, replace if necessary
Replace Air compressors	N/A	Every 5 years	Refer to section 5.3.5	Check for durability issues and quality, replace if necessary
Replace coolant and DI filter replacement	20000	Every 2 years	Refer to section 5.4.3	Ethylene Glycol 50/50
Replace coolant tank level switch	N/A	Every 2 years	Refer to section 5.4.5	Check for durability issues and quality, replace if necessary
Replace coolant flow control valves	N/A	Every 2 years	Refer to section 5.4.6	Check for durability issues and quality, replace if necessary

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	*Interval			
Task	Hours	Month(s)	References	Comments
Replace coolant pump motor bearings	20000	Every 5 years	Refer to section 5.4.7	Check for vibration levels depending on RPM of the motor
Replace coolant pump wear parts and shaft seals	20000	Every 5 years	Refer to section 5.4.7	Check for pump performance and seal leakages, replace if necessary
Replace DI filter	1500	3	Refer to section 5.4.8	Replace if conductivity is too high
Replace H2 sensor	6000	Every 1 year	Refer to section 5.5.3	Check for durability issues and quality, replace if necessary
Replace Smoke detector	6000	Every 1 year	Refer to section 5.5.8	Check for durability issues and quality, replace if necessary
Replace Ventilation fans	N/A	Every 5 years	Refer to section 5.5.9	Check for durability issues and quality, replace if necessary
Replace H2 enclosure water ingress sensor	N/A	Every 2 years	Refer to section 5.5.5	Check for durability issues and quality, replace if necessary
Replace fuel cell stack assembly	34000	Every 5 years	Refer to section 5.5.10	Check for operating conditions, polarizations, and leaks in the module.
Replace ventilation air intake filter	3000	6	Refer to section 5.7.1	Service interval to be validated for each customer / application. Validation should occur no later than initial 1000 hours.
Replace cabinet water ingress sensor	N/A	Every 2 years	Refer to section 5.7.2	Check for durability issues and quality, replace if necessary
Replace HRB and Coolant motor controllers	N/A	N/A	Refer to section 5.6.4	In case of failure or misreading in the system, it is recommended to replace

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Maintenance Plan, FCwave 200kW	Document ID: MAN001-C			Revision: 0
	*Interval			
Task	Hours	Month(s)	References	Comments
Replace Air compressor controllers	N/A	N/A	Refer to section 5.6.5	In case of failure or misreading in the system, it is recommended to replace
Replace Current Transducers	N/A	N/A	Refer to section 5.6.6	In case of failure or misreading in the system, it is recommended to replace
Replace Voltage Contactors	N/A	N/A	Refer to section 5.6.7	In case of failure or misreading in the system, it is recommended to replace
Replace Voltage Transducers	N/A	N/A	Refer to section 5.6.8	In case of failure or misreading in the system, it is recommended to replace
Replace Fuses	N/A	N/A	Refer to section 5.6.9	In case of failure or misreading in the system, it is recommended to replace
Replace Bleed down and Precharge resistors	N/A	N/A	Refer to section 5.6.10	In case of failure or misreading in the system, it is recommended to replace
Replace Diodes	N/A	N/A	Refer to section 5.6.11	In case of failure or misreading in the system, it is recommended to replace
Replace Electric panel ventilation fans	N/A	N/A	Refer to section 5.6.12	In case of failure or misreading in the system, it is recommended to replace
Replace High Voltage Panel	N/A	N/A	Refer to section 5.6.14	In case of failure or misreading in the system, it is

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Maintenance Plan, FCwave 200kW	Document ID: MAN001-C			Revision: 0
	*Interval			
Task	Hours	Month(s)	References	Comments
				recommended to replace
Replace Low Voltage Panel	N/A	N/A	Refer to section 5.6.15	In case of failure or misreading in the system, it is recommended to replace
Replace MCU	N/A	N/A	Refer to section 5.6.16	In case of failure or misreading in the system, it is recommended to replace
Replace Temperature sensors	N/A	N/A	Refer to section 5.8	In case of failure or misreading in the system, it is recommended to replace
Replace Pressure sensors	N/A	N/A	Refer to section 5.9	In case of failure or misreading in the system, it is recommended to replace
* Whichever comes first.				

Table 5-1: Maintenance Plan – MAN001-C

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