# ACLS – The Life Support Rack – for Accommodation on the ISS

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Deutscher Luft- und Raumfahrtkongress 2018
4 – 6 September 2018 - Friedrichshafen


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# ACLS Overview

- ACLS is a technology demonstrator and stands for "Advanced Closed Loop System". It is a Life Support Rack originally designed for a crew of 3 and for up-to 10 years of on-orbit operations.

- ACLS will be launched in Sept. 2018 with HTV-7 from Tanegashima Space Center, Japan.

- ACLS will be installed in the US Lab Module of the ISS on position (LAB1) P1.

- About 4 – 6 weeks of in-orbit commissioning are considered. Afterwards ACLS will provide services ($CO_2$ removal, $O_2$ generation and water production) to the ISS.

**Fig. 1:** ACLS – The Life Support Rack





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# ACLS Objectives

- ACLS is integrated in an ISPR Rack and covers the following life support functions:

  – removal of carbon dioxide from the ISS atmosphere via a regenerative adsorption & desorption process
  → Technology based-on a Solid Amine resin

  – supply of breathable oxygen via electrolysis of water
  → Technology based-on a Fixed Alkaline Electrolyser

  – catalytic conversion of carbon dioxide with hydrogen to water and methane
  → Technology uses a Two Stage Sabatier Reactor Design

**Fig. 2:** ACLS Integration in HTV-7; day 17/04/18





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# ACLS Main Characteristics

**Fig. 3:** ACLS in HTV-7

- Sized for crew of 3:
  - Scrubs min. 3 kg/day $CO_2$ (at 3 mmHg or 0,4vol% $CO_2$ in cabin air)
  - Produces ≈ 2.5 kg/day $O_2$
  - Produces ≈ 1.2 kg/day water
- Needs ≈ 3 kg/day potable water for $O_2$ production from the POTABLE WATER BUS.
- Needs waste water for steam regeneration of the $CO_2$ adsorber resin from the WASTE WATER BUS.
- ACLS uses MTL (MODERATE TEMPERATURE COOLING LOOP) for thermal control.
- ACLS Power Consumption in full SYS-OPS: 2.1 kW average, < 4.5 kW peak.





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# ACLS Design Description

Photobioreactor CO2 I/F

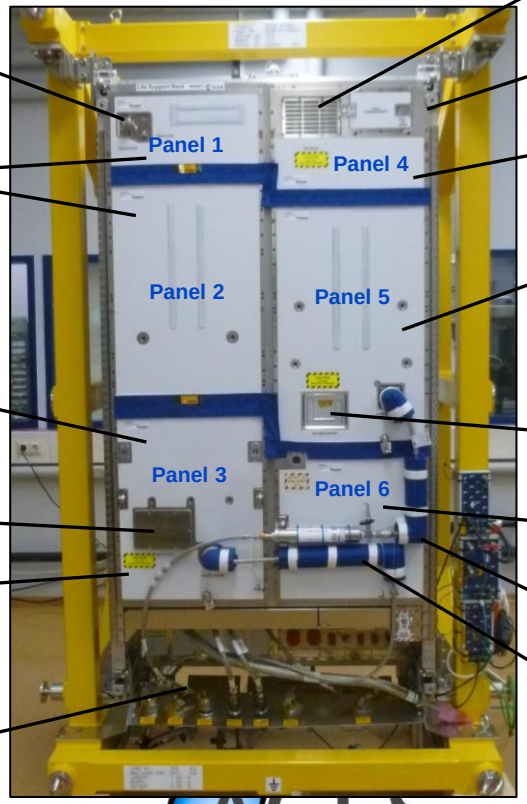
CCA S/S (Drw#1, #2)
Function: removal of carbon dioxide from the spacecraft atmosphere

CRA S/S (Drw#4)
Function: production of water from $CO_2$ and $H_2$ (service provision) to decrease water up-load to ISS

Air outlet to cabin

CCA S/S (Drw#3)
Function: air and water management

UIP




Air inlet from cabin

Tool Compartment

Avionics (Drw#8)

OGA S/S (Drw#6)
Function: supply of breathable oxygen via electrolysis

O2 injection port to cabin

Avionics (Drw#7)

Feed Water Supply with ACTEX cartridge

Waste Water Supply

**Fig. 4:** ACLS Front view

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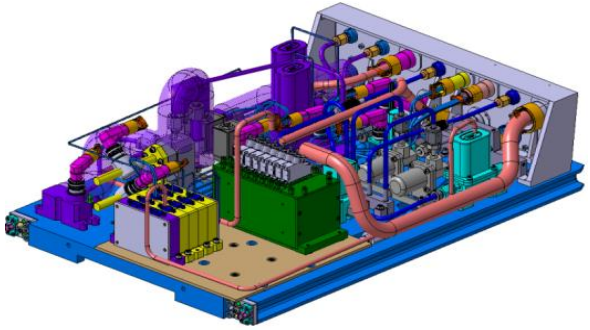
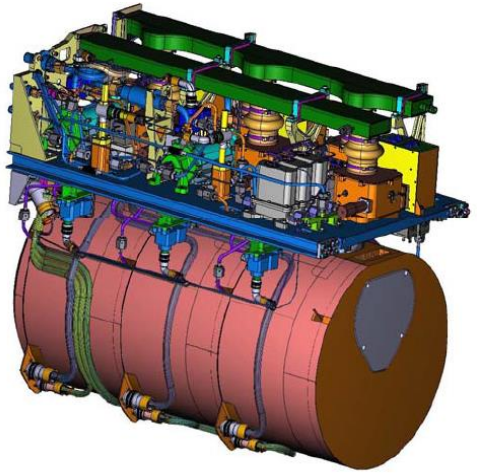
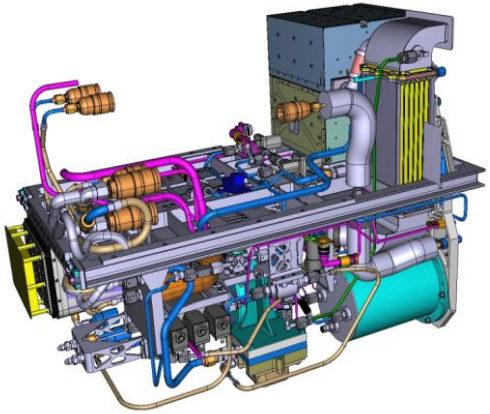
# CCA S/S: Carbon Dioxide Concentration Subsystem consists of Drw#1, #2, #3



Drawer#1 with $CO_2$ Management and Avionics



Drawer#2 with $CO_2$ adsorber beds



Drawer#3 with Air and water Management





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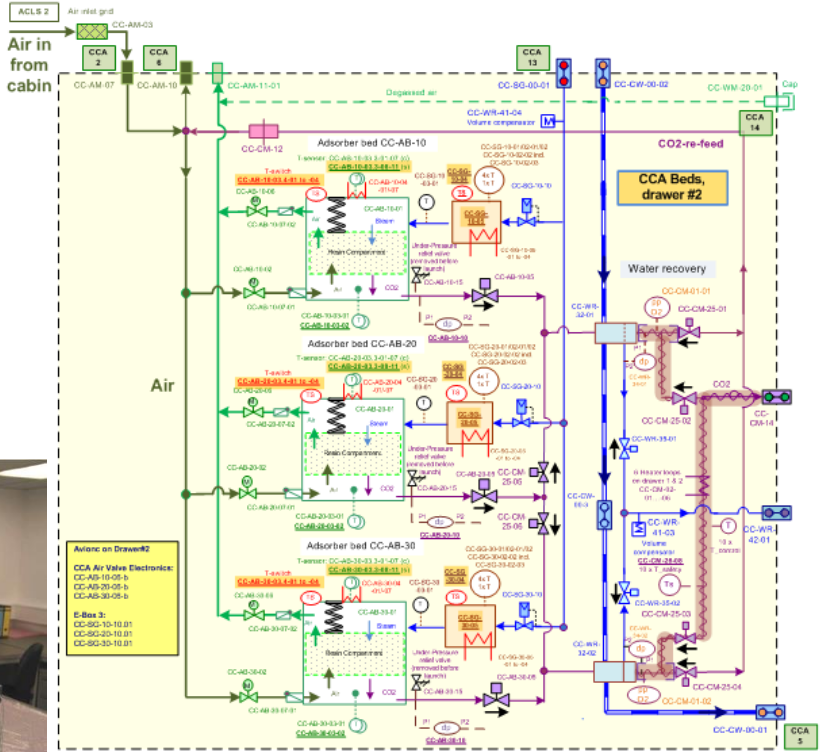
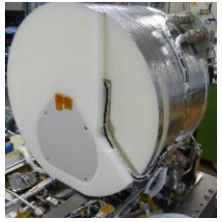
# CCA S/S: CCA Adsorber Section (Drw#2)

- CCA fan draws cabin air through adsorber beds
- $CO_2$ adsorption on Astrine™ resin (solid amine; very good efficiency at low $CO_2$ levels; nominal working point: 4 hPa $CO_2$ air inlet concentration)
- $CO_2$ desorption at 105°C steam (3-bed system); desorption of $CO_2$ overlapping in order to provide smooth $CO_2$ flow to CRA; no $CO_2$ buffer tank needed.
- $CO_2$ Desorption at ambient pressure, no compressor needed
- $CO_2$ drying stage integrated



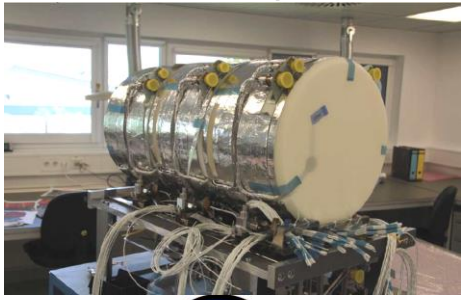
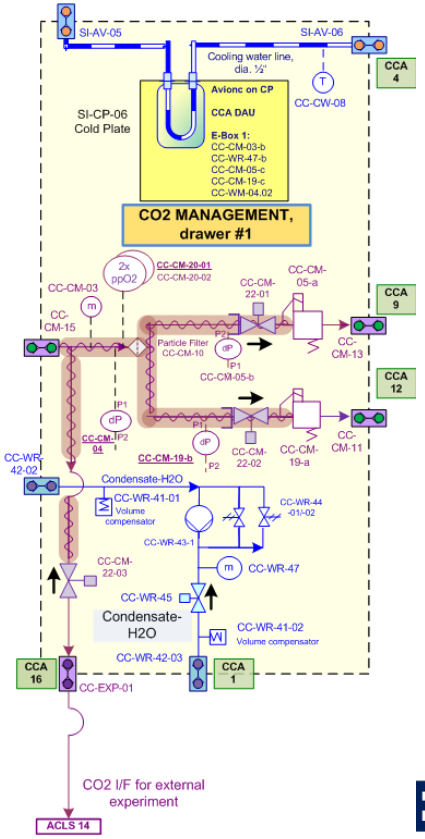


*Photo: Drw#2*

# CCA S/S: CCA $CO_2$ Management Section (Drw#1)

- Drw#1 includes the $CO_2$ Mgmt. section to observe the $CO_2$ quality (mass flow rate, $CO_2$ concentration)
- Automatic routing of $CO_2$ flow either to $H_2/N_2$ Waste GAS (CCA SA-OPS) or to Sabatier reactors (ACLS SYS-OPS).
- $CO_2$ supply I/F for external experiment located on Drw#1 (for the Photobioreactor).
- $CO_2$ flow rate range 0 – 4.5 g/min and 2.1 g/min nominal
- $CO_2$ 98 Vol.-%; rest water vapour and air
- $p_{amb}$, T approx. 35°C, $T_{dew}$ point approx. 22°C

SA-OPS = Stand alone operation
Sys-OPS = Closed-loop system operation

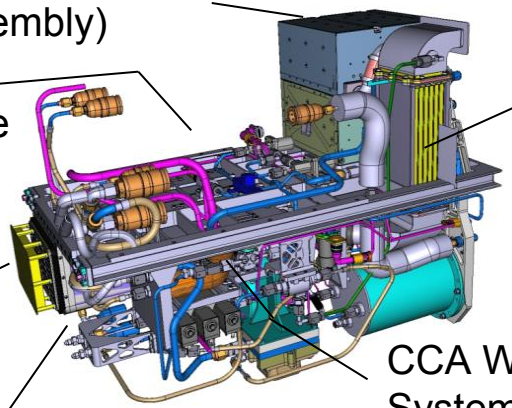


# CCA S/S: Air and Water Management (Drw#3)

CWSA (Condensate Water Separater Assembly)

available space for Drw#4

Air to cabin



CHX to reduce humidity in air released to cabin

Air Managment incl.:
- CHX/CWSA
- Fan/Muffler
- Outlet Grid

CCA Water Management System (for Waste Water) incl.:
- UV Treatment Unit
- Gas Trap
- De-Ionisation Unit
- CFU Filter
- Water Buffer Tank

*Photo: Drw#3*





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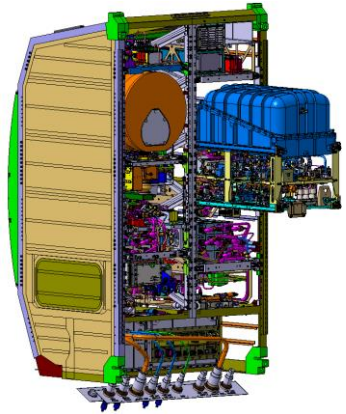
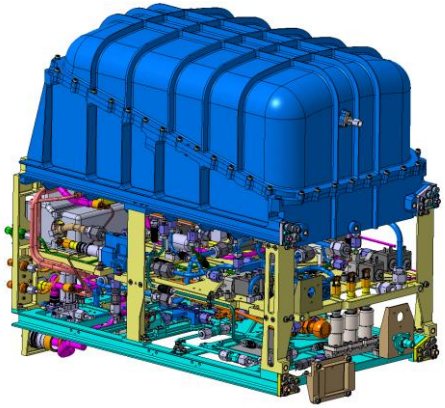
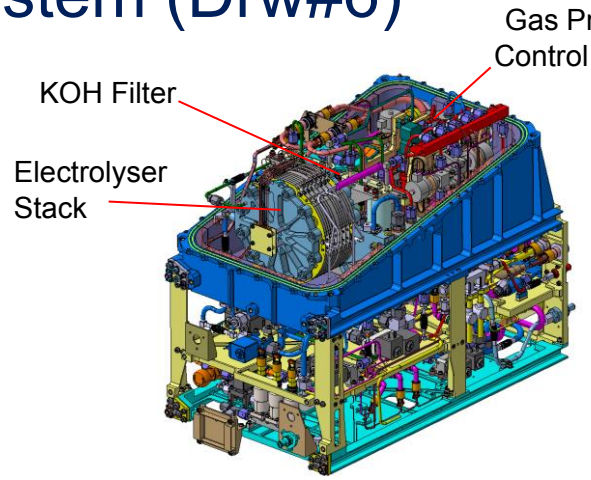
# OGA S/S: Oxygen Generation Subsystem (Drw#6)



Drw#6 extracted from Rack



Drw#6 removed from the Rack




Drw#6 – Safety DOME opened

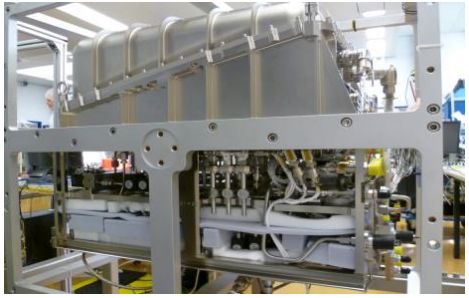


*Photo: Drw#6*

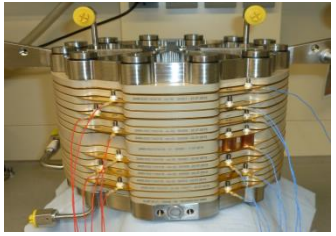


*Photo: Electrolyzer Stack*





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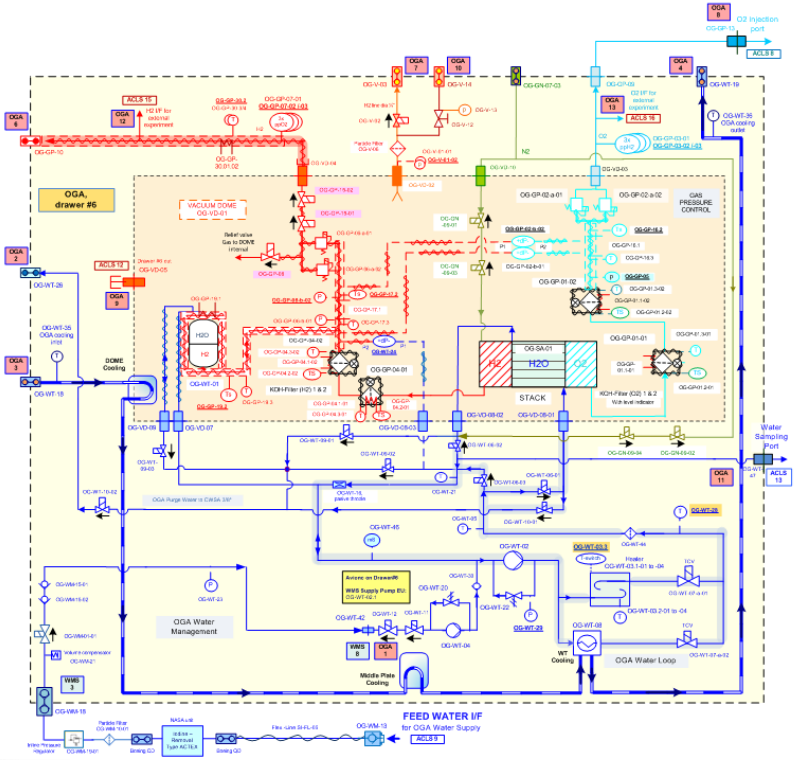
# OGA S/S: Oxygen Generation Subsystem (Drw#6)

- Fixed Alkaline Electrolyser: the electrolyte (KOH) is fixed in a diaphragm between the electrodes; feed water is evaporated via a porous membrane towards the electrode in the $H_2$ compartment; no moving parts, no rotating phase separators, no pumped KOH loop.
- High electric efficiency, low cell voltage (1.6 V BOL)
- Vacuum dome as safety containment; KOH absorbers (filter) in $O_2$ and $H_2$ gas lines for safety





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# CRA S/S: Carbon Dioxide Reprocessing Subsystem (Drw#4)

- Drw#4 is mechanically connected to Drw#3 but can be removed.
- Drw#4 includes two stage reactors to guarantee high hydrogen conversion (> 90%)
- High temperature for fast reaction in reactor 1 (approx. 550°C)
- Lower temperature in reactor 2 (<250°C) for high conversion
- $H_2/CO_2$ molar ratio 2 – 4
- Reactor operating pressure < ambient pressure to avoid leakage of reactant gases to cabin
- Water recovery (WRU): capillary condensing system without centrifugal water separator

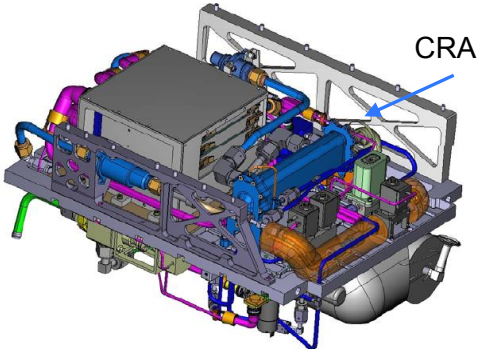


*Photo: Sabatier reactors*





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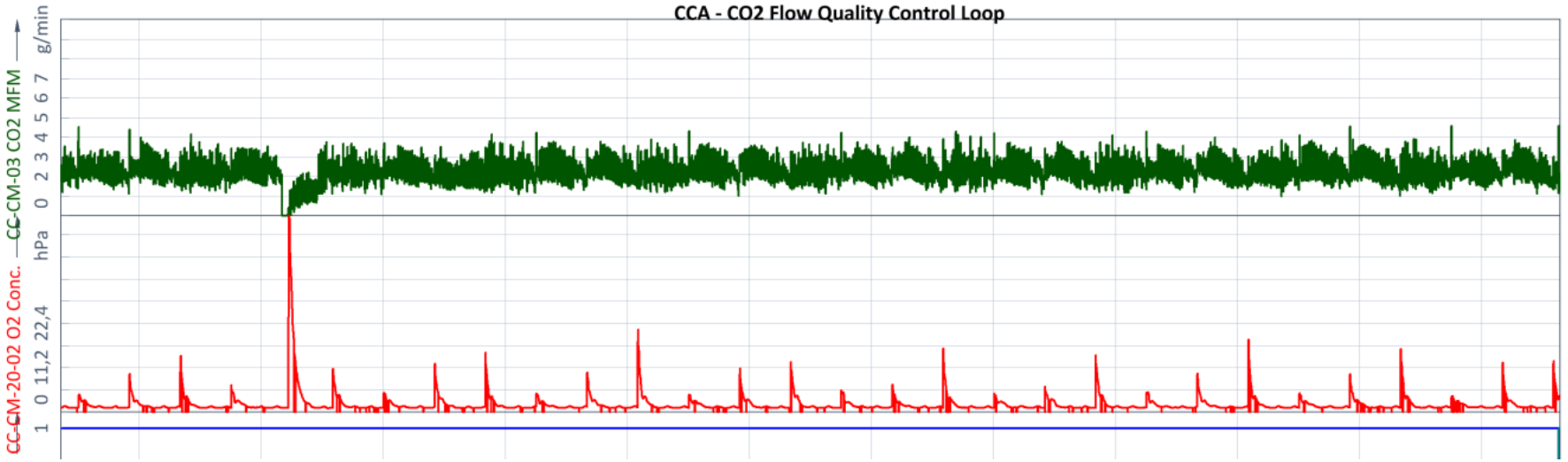
# Performance Test results: CCA




**Green curve:** CCA CO2 flow to vent line or to Sabatier Reactors

**Red curve:** CCA CO2 Quality high with low residual O2





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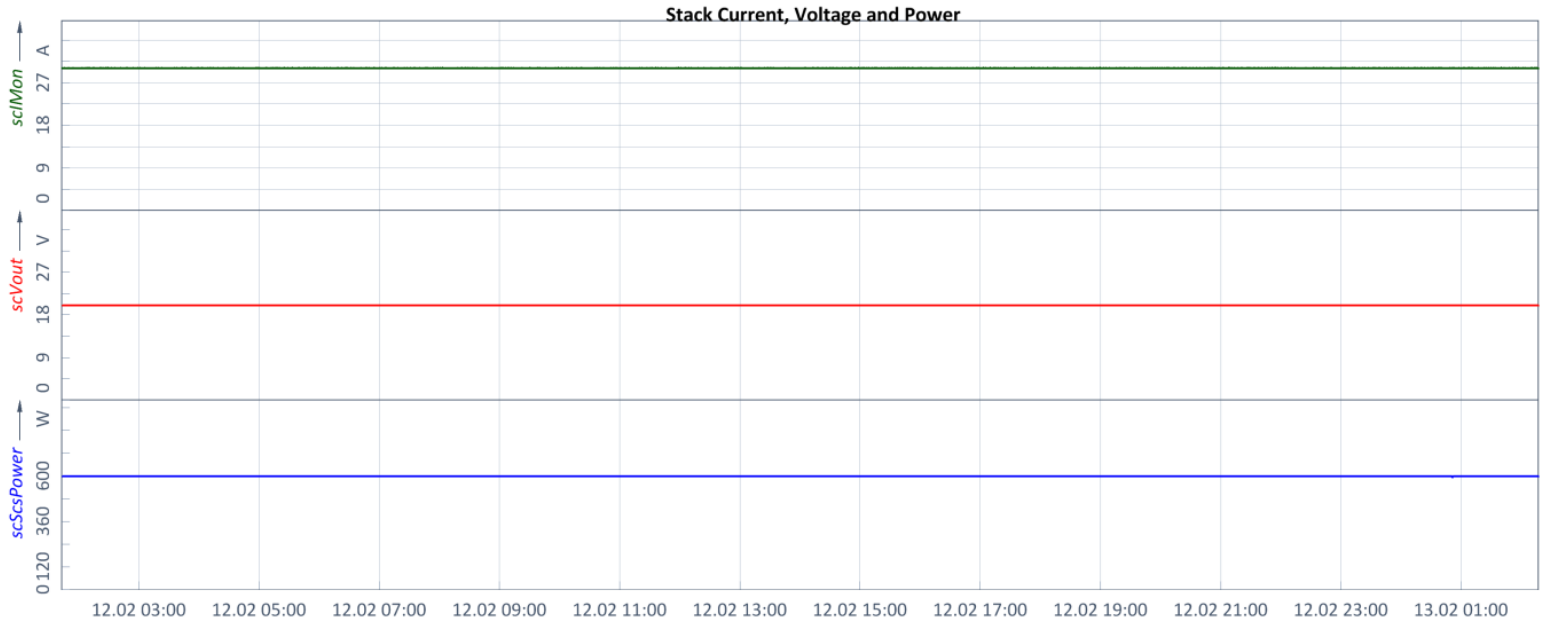
# Performance Test results: OGA (I)




**OGA:** electrolyser operational parameters





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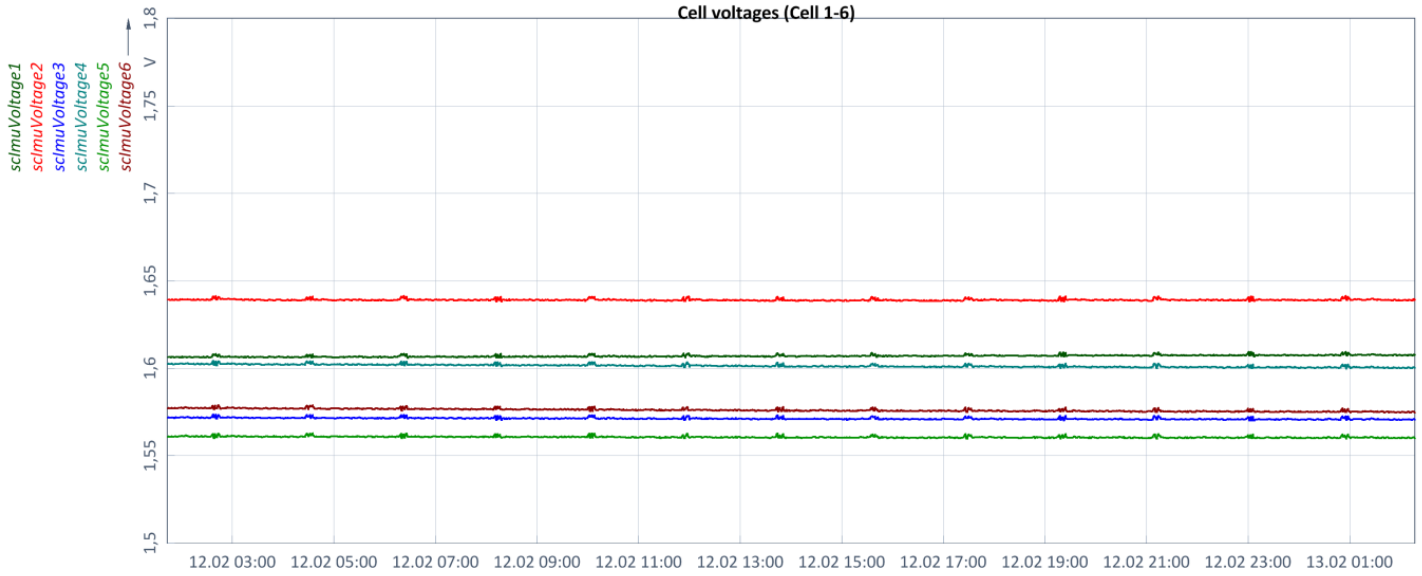


**OGA:** electrolyser cell voltage monitoring (cells 1 – 6)





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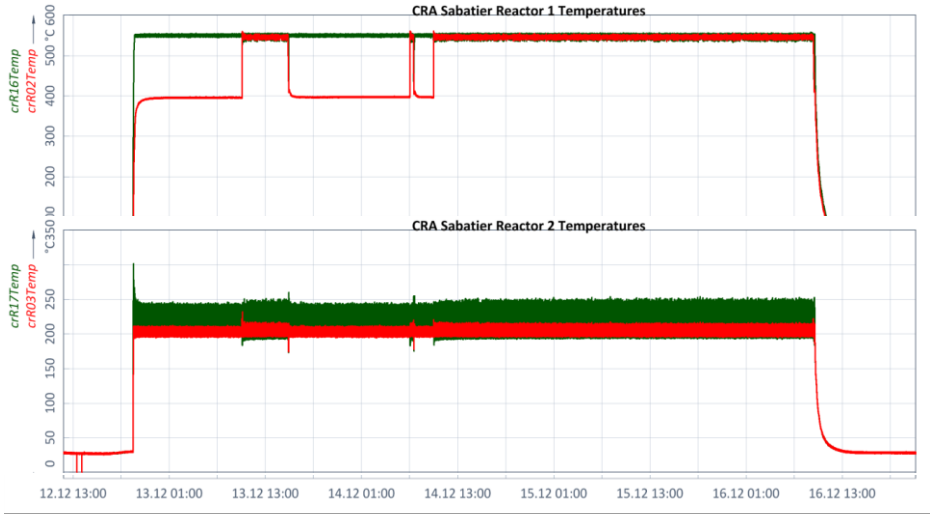
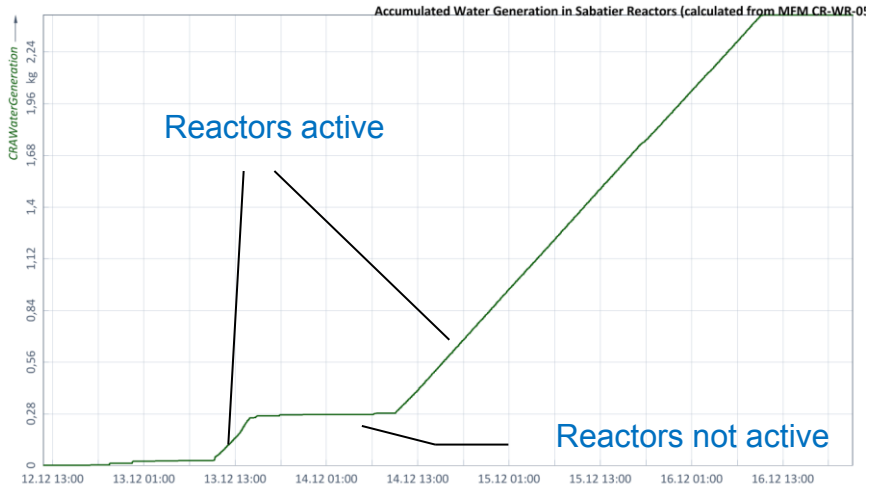
# Performance Test results: CRA




CRA: Reactor temperatures




CRA: accumulated water generation





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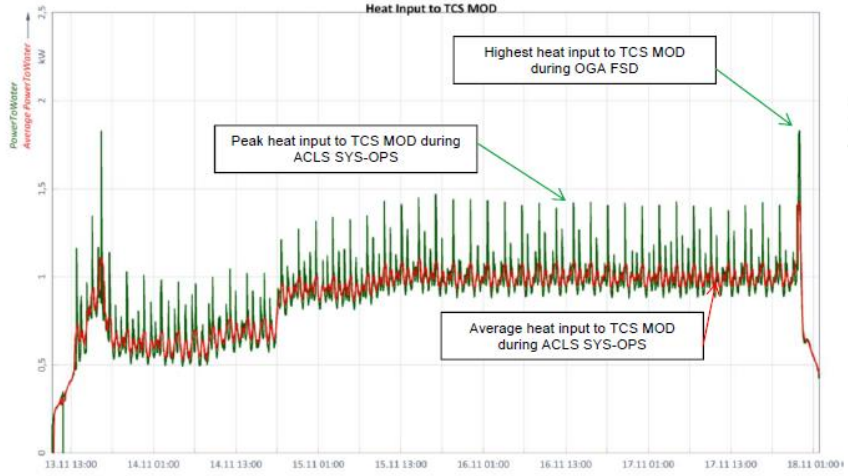
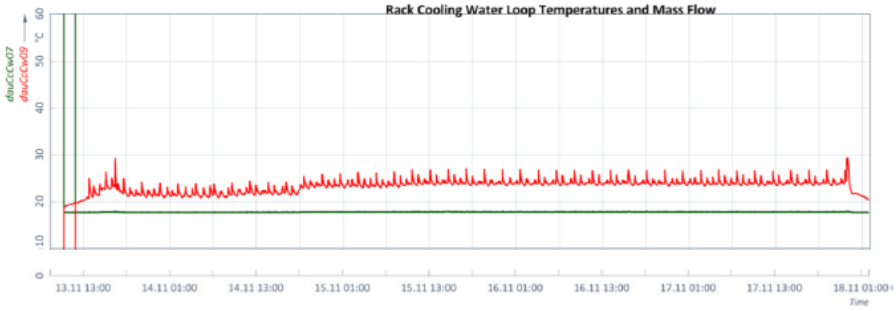
# I/F Test results: TCS MOD




Heat Input to TCS MOD
@ Coolant flow rate approx. 150 kg/h




T inlet and outlet at TCS MOD
Requirement: T outlet < 49°C





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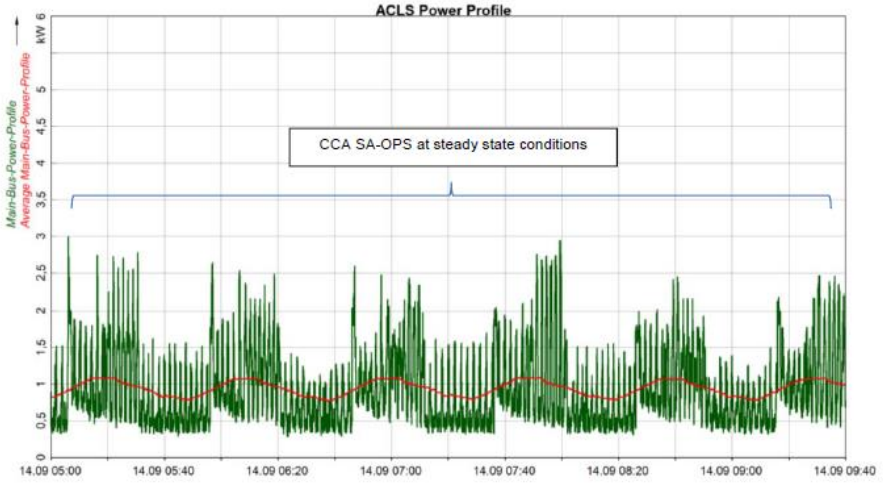
# I/F Test results: Power Profiles




CCA in SA-OPS


OGA in SA-OPS

| ACLS Operational Status | Average Main Power Bus consumption [kW] | Min. Power [kW] | Max. (Peak) Power [kW] |
|---|---|---|---|
| Stand-By (SBY) | 0.25 | 0.2 | 0.3 |
| CCA SA-OPS | 0.9 | 0.3 | 3 |
| OGA SA-OPS | 1.3 | 1.1 | 2 |
| CCA SA-OPS and OGA SA-OPS | 2.0 | 1.2 | 4.1 |
| ACLS SYS-OPS | 2.1 | 1.2 | < 4.5 |





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# Thank you for your attention

## Open questions and discussion




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