CLOU BESS PRODUCT REVIEW

Aero-C and Aqua-C Technology Review Report

SHENZHEN CLOU ELECTRONICS CO., LTD.

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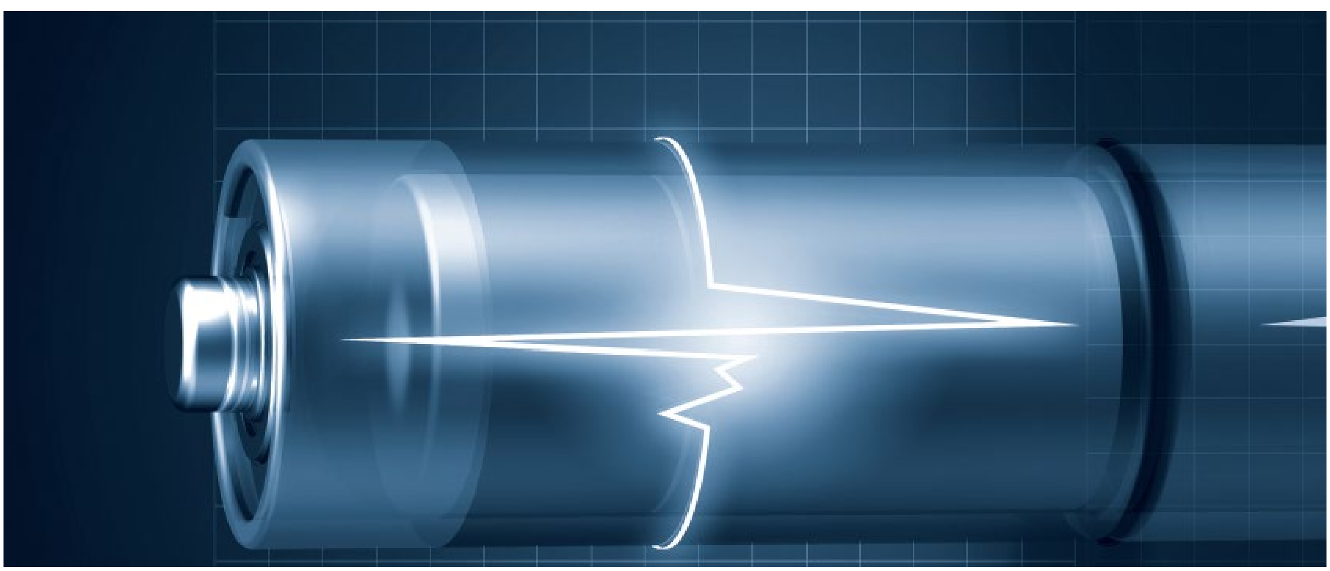

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List of abbreviations

The following table lists some of the abbreviations used in this Report.

Acronym	Abbreviation
AC	Alternating Current
Ah	Ampere-hour
BAMS	Battery Array Management System
BCMS	Battery Cluster Management System
BESS	Battery Energy Storage System
BMS	Battery Management System
BMU	Battery Management Unit
BOL	Beginning of Life
CAGR	Compound Annual Growth Rate
CBMU	Cluster Battery Management Unit
CC	Central Control or Constant Current (depending on context)
CFD	Computational Fluid Dynamics
CFM	Cubic Feet per Minute
C-rate	Current Rate
C&I	Commercial and Industrial
DC	Direct Current
DNV	Det Norske Veritas
EMMU	Environmental Monitoring Management Unit
EMS	Energy Management System
EOL	End of Life
ERG	Emergency Response Guide
ESS	Energy Storage System
FIFO	First In, First Out
FAT	Factory Acceptance Test
FSS	Fire Suppression System
HMA	Hazard Mitigation Analysis
HMI	Human Machine Interface
HVAC	Heating, Ventilation, Air Conditioning
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IP	Intellectual Property or Ingress Protection (depending on context)
kWh	Kilo Watt-hour
LFL	Lower Flammability Limit
LFP	Lithium Iron Phosphate ($LiFePO_4$)
LTSA	Long Term Service Agreement
MBMU	Module Battery Management Unit
MES	Manufacturing Execution System
MSD	Manual Service Disconnect

NG	Not Good
O&M	Operation and Maintenance
P	Power
PCS	Power Conversion System
PPE	Personal Protection Equipment
Q	Quarter
RTE	Round-trip Efficiency
R&D	Research and Development
SAT	Site Acceptance Test
SOC	State of Charge
SOH	State of Health
UL	Underwriters Laboratories
V	Voltage
Wh	Watt-hour

EXECUTIVE SUMMARY

Company Overview

CLOU is an electrical equipment manufacturer which was established in 1996 and primarily focuses on energy storage and smart grid technologies, especially in the energy storage business. CLOU has achieved significant milestones, including manufacturing capacity expansion by launching its Yichun Gigafactory in 2021. In 2023, Midea, a Fortune Global 500 company, became the first shareholder of CLOU.

CLOU offers a wide range of battery energy storage system (BESS) product lines for both consumer and business use. The company has filed over 1,300 patents in various fields, including about 400 patents related to energy storage technologies.

BESS Product Review

The focus of this review is on the following products:

- Aero-C air cooling 3.0 MWh BESS (0.25P or 0.3P operations)
- Aqua-C liquid cooling 3.7 MWh BESS (0.5P operation)

Both Aero-C and Aqua-C implements all-in-one design and is non-walk-in BESS system, which is typical design for BESS systems. Battery cells used in Aero-C and Aqua-C are primarily supplied by REPT and Hithium.

CLOU conducted performance tests include capacity test, round-trip efficiency (RTE) test, degradation test, and high temperature test on BESS systems. Following conclusions can be drawn based on the test results:

- The charge energy and discharge energy of both Aero-C and Aqua-C exceed the rated energy
- The RTE of Aero-C and Aqua-C are 94.2% and 94.3% respectively, both of which exceed design criteria of 94%.
- The temperature ranges (T_{max} – T_{min}) within a single cell of the most significance in Aero-C and Aqua-C are maintained within 4 °C and 3 °C, respectively.
- DNV reviewed the simulated degradation performance of Hithium and REPT's 280 Ah cells separately. The simulations conclude that it is expected to take 15 and 20 years for REPT and Hithium 280 Ah cells to reach 70% SOH, respectively, assuming the cells operate at 0.5P, 1 cycle per day at ambient temperature between 20-35 °C. However, the degradation of system may be different from the simulations of cells due to its characteristics and working conditions. No degradation performance data was provided for the review.
- DNV has reviewed thermal management system of Aero-C in the following aspects – 1) thermal load calculation; 2) air duct design; 3) CFD simulation analysis. DNV reviewed the most severe case among all cases CLOU has simulated, that was 0.3P operation at 45 °C ambient temperature. The simulation results indicated that the maximum temperature difference across the container is 9.7 °C. DNV suggests CLOU performing real life test at 45°C ambient temperature and cross comparing both simulated and experimental results.
- DNV reviewed separately the electrochemical performance and safety of REPT and Hithium 280 Ah cells, both of which have already been reviewed by DNV in detail in separate reports [1] [2].

Safety and Compliance Evaluation

CLOU has obtained several certifications and test reports for Aero-C module, rack and system, such as UL 1973, UL 9540A. However, many necessary certifications are still ongoing, especially for Aqua-C products, which are expected to complete in 2024 Q3.

CLOU's Aero-C and Aqua-C demonstrated that they were suitable for outdoor use and demonstrated to comply with the requirements for seismic environments installation (IEEE 693 high seismic level). Fire suppression system and explosion protection measures are employed in the BESS. The ventilation system of Aqua-C for explosion prevention has been verified via CFD simulations to show the compliance to NFPA 69 and to demonstrate its effectiveness.

Hazard mitigation analysis and emergency response guide shall be elaborated based on the specific characteristics of the BESS.

Installation and Integrated System Review

CLOU provided detailed user manual and maintenance manual, which is aligned with industry standard practices in general.

Quality System and Manufacturing Review

The BESS production facility in Yichun CLOU is well organized and clean. MES, SAP, Teamcenter systems are applied in the facility for manufacturing and quality management. This is typical for manufacturing processes with consistent quality control.

Product Support

CLOU has established certain global support network. However, the service quality and response time vary based on the location, scale, and the quality of specific project.

CLOU provides standard warranty agreement and long term service agreement (LTSA) framework. The 3-year standard warranty covers operation and maintenance (O&M), technical support, annual inspection, performance and availability guarantee, spare parts, etc. DNV opines the terms are in line with the industry standard. However, DNV has not received and reviewed the detailed information on performance guarantee and availability guarantee under Technical Agreement.

The longest product warranty period that CLOU may offer is 20 years. Based on current industry practices, there is no reliable evidence which could demonstrate 20 years life of BESS. DNV recommends that detailed warranty terms and LTSA shall be reviewed and evaluated judiciously for specific project.

1 INTRODUCTION

Shenzhen CLOU Electronics Co., Ltd. (the “Customer” or “CLOU”’) has engaged DNV China Company Limited (hereinafter “DNV”) to complete a technical due diligence evaluation of CLOU’s battery energy storage system (“BESS” or “ESS”) product. This evaluation is intended to serve as third-party vetting of the CLOU’s BESS product. Within this report, DNV reviewed the company, the BESS designs, and integration capabilities. DNV opines on CLOU’s specification, design for functionality and safety, performance, service infrastructure, guarantees and warranties, and manufacturing capabilities.

DNV is a leading authority on consulting, implementation, research, testing, and certification of solutions for the energy sector. Recognized as a global leader in energy storage consulting, DNV provides strategic advisory services, innovative modeling tools, and independent testing and certification to clients across various sectors of the energy industry. DNV operates as an independent entity without ties to any vendor, investments, affiliations, or financial interest with any equipment or service providers.

1.1 Report scope of work

The primary objective of this report is to assess factors that would affect the final product’s performance and reliability in the field and the company’s ability to deliver and service the products within its stated timeframe. Such factors will include the product design, quality of materials, product performance, regulatory compliance, reliability tests, and the manufacturing and quality control processes. DNV has divided the technical due diligence review into several main topic areas for evaluation as illustrated in Figure 1-1.

Figure 1-1 Report Structure

As part of the CLOU’s technology bankability review, DNV performed an inspection of CLOU’s manufacturing plant in Yichun, China. The objective was to confirm that CLOU has the processes in place to deliver the expected quantity and quality of the product for meeting the required standards in reliability and safety.

1.2 Approach

This report represents DNV’s final Independent Engineering review intended for financial institutions, CLOU’s customers, and project developers. DNV is uniquely qualified to conduct this study due to its extensive background and experience in solar, wind, and energy storage independent engineering and technology due diligence work.

DNV's approach to completing the technology review includes three levels of assessment. First, DNV will verify that the product and process claims align with product documentation (e.g., roundtrip efficiency used in models matches the specification sheet), that there is consistency in the preparation of materials (e.g., the nomenclature for the product matches throughout), and that the claimed values are aligned with expectations based on industry norms. Second, DNV will compare the specified values to test data, validating the claims. Depending upon what claims are being assessed, this test data may be at a bench scale, from simulations, from demonstration or pilot sites, or from third-party certifiers. The granularity and rigor of these tests impact the strength of DNV's opinion when comparing the tested results to the claimed characteristics, but typically this information will allow DNV to determine if the system is designed and tested appropriately for the intended application. Third, DNV will review real world or field data. This information will provide confidence in performance over time, under a variety of uncontrollable conditions, and for a statistically meaningful number of systems. At the current maturity of the energy storage industry, DNV is not typically provided with a sufficient amount of field data, nor is there sufficient consistency across the industry, for there to be a single, industry- and financier-accepted definition for a "proven" technology. However, DNV can identify risks and recommend mitigants, based on parallels to other industries.

To perform the assessment, DNV relied on documentation provided by CLOU, a factory visit, as well as phone calls with CLOU staff associated with the topic areas covered. Further, the following customer meetings were conducted by DNV to align and close the gaps with respect to documentation provided by CLOU via Virtual data room.

1.3 Assumptions

This report summarizes the DNV assessment of the technology and relies on the accuracy of the information provided by CLOU. CLOU has been forthcoming in providing the data that DNV has requested; where data was not provided or was incomplete is noted as such within the report. Within this report, DNV highlights the risk of any missing or incomplete data and reviews and opines on the information that has been provided to date.

This report is based on some information not within the control of DNV. DNV believes that the information provided by others is true, correct, and reasonable for the purposes of this report. DNV has not been requested to make an independent analysis or verification of the validity of such information. DNV does not guarantee the accuracy of the data, information, or opinions provided by others.

In preparing this report and the opinions presented herein, DNV has made certain assumptions with respect to conditions that may exist, or events that may occur in the future. DNV believes that these assumptions are reasonable for the purposes of this report, but actual events or conditions may cause results to differ materially from forward-looking statements.

2 COMPANY OVERVIEW

2.1 Company overview

In 1996, CLOU was established in Shenzhen and began its operations in the electric power business. The company was listed on the Shenzhen Stock Exchange under the stock code (002121) in 2007. In 2009, CLOU entered the Energy Storage System (ESS) market and acquired the Power Conversion System (PCS) company in 2012. CLOU's latest achievement in 2021 was the manufacturing capacity expansion by launching its Yichun Gigafactory. In 2023, Midea, a Fortune Global 500 company, became the first shareholder of CLOU. Midea was founded in 1968 and has grown from a local appliance manufacturer to be one of the largest companies in China and the Top 200 in the world. Midea will continue supporting CLOU's business in Energy Storage and Smart Grid. Figure 2-1 presents the major business milestones CLOU has made until 2023. [3]

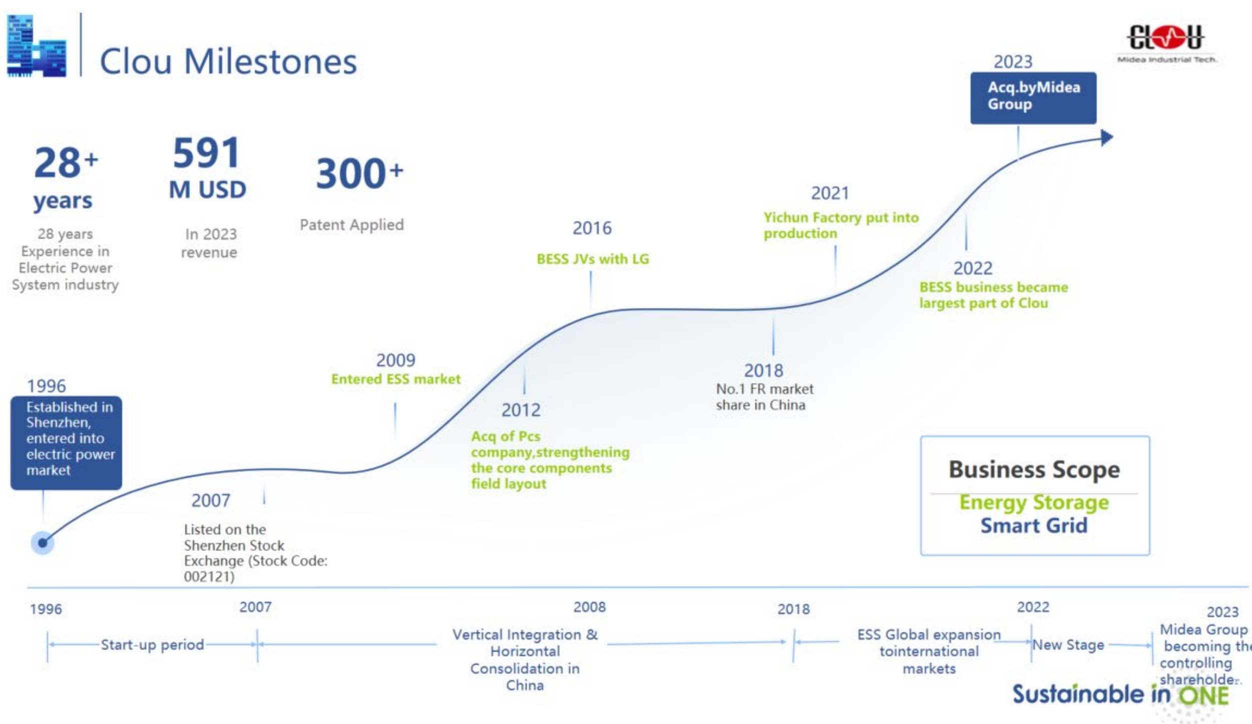


Figure 2-1 CLOU milestones [3]

Figure 2-2 shows the overview of CLOU's facilities for Research and Development (R&D)/Manufacturing of ESS in China. The production capacity of BESS and PCS is 8 GWh/y (Yichun) and 1 GW/y (Sichuan), respectively. By Q3 2024, CLOU plans to increase its production capacity for BESS to 34 GWh/y (Yichun 8 GWh/y, Guangdong 23 GWh/y, overseas 3 GWh/y) and 6 GWh/y (Sichuan 1 GW/y, Guangdong 5 GW/y) for PCS.

Figure 2-2 CLOU R&D Center/Manufacture Overview for ESS

2.2 Product history

Table 2-1 indicates the recent BESS product lines. CLOU has various types of BESS product lines from consumer products (Residential) to business products (Commercial and Industrial (C&I)) and utility scale products. CLOU has designed and produced not only ESS containers but also PCS systems over 10 years.

Table 2-1 BESS Product Lines

Application	Year	Capacity	Format	Cooling Method	Comment
Commercial and Industrial (C&I)	2022	2.6 MWh	20 ft container	Air	Battery O&M platform in China
	2023	3.7 MWh	20 ft container	Liquid	Battery O&M platform overseas
	2024	4.2 MWh	20 ft container	Liquid	300 Ah + cell application
	2022	100 kW/200 kWh	Outdoor cabinet	N/A	GBT verified
	2023	100 kW/200 kWh	Outdoor cabinet	N/A	CE & UL listed
	2023	372 kWh	Outdoor cabinet	Liquid	N/A
Utility	2022	1.5 MW/1.5 MWh	20 ft container	Air	UL
Residential	2022	5-8 kW (Single phase) 9, 13.5, 18, 27 kWh DC 80-500 V	Rack	N/A	CE
	2022	10-15 kW (single phase) 13.5, 18, 27, 36 kWh DC 200-800 V	Rack	N/A	CE
	2023	7-10 kW (Split phase)	Rack	N/A	UL

Figure 2-3 shows the typical BESS cases delivered by CLOU globally. Total 581.3 MW / 2,884.2 GWh BESSs of CLOU has been installed as of October 2023, in which 129.0 MW / 1,712.5 MWh is in North America.

Figure 2-3 Typical BESS cases under delivery

2.3 Intellectual property

CLOU, a company that has applied for approximately 2,000 patents, has filed over 1,300 patents in a variety of fields, including about 400 related to energy storage technologies, such as battery module, Energy Management System (EMS), Battery Management System (BMS), and PCS.

To protect CLOU’s own business, it's crucial to have Intellectual Property, such as patents. Although DNV has not reviewed CLOU's patents in detail in this report, having more patents can be beneficial in case of patent litigation.

2.4 Financial status

Figure 2-4 shows the revenue of CLOU from 2018 to 2023. As per the chart, the revenue decreased and fluctuated after 2018. However, the revenue increased from 2022, and the compound annual growth rate (CAGR) is around 9% from 2021 to 2023.

CLOU invested 233 million CNY in R&D, which is about 7% of its annual revenue in 2022, as per the company's annual report. This investment ratio is similar to that of other BESS-leading companies.

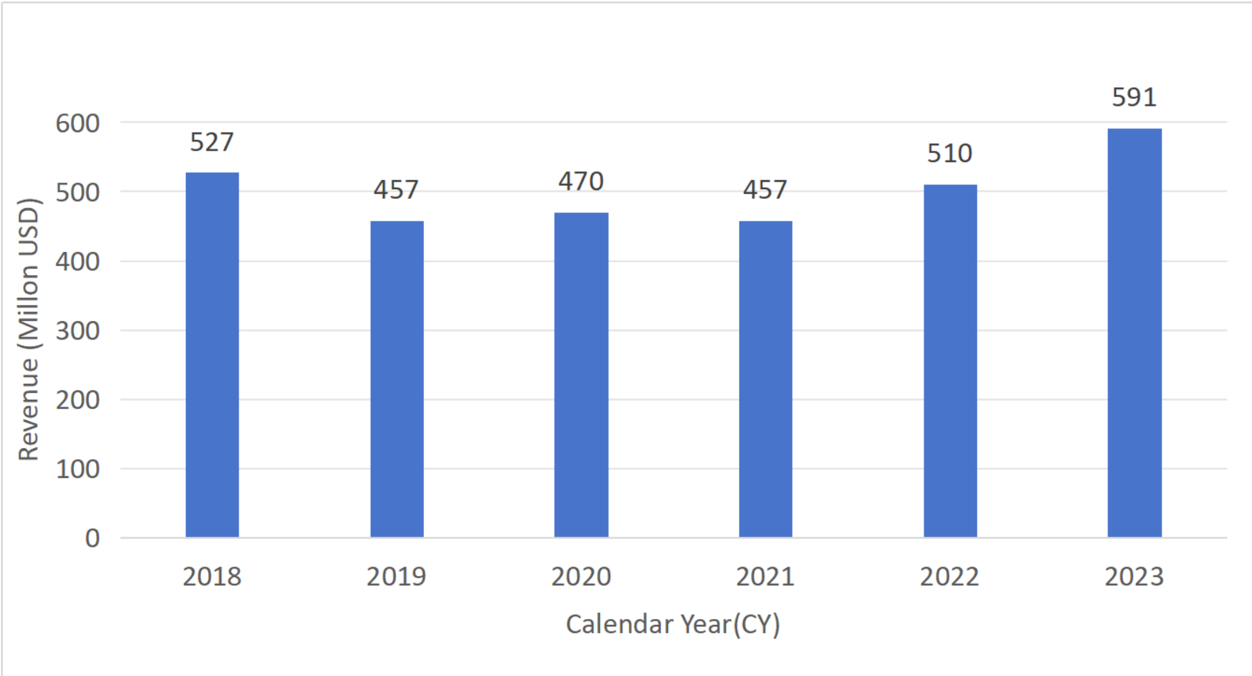


Figure 2-4 CLOU Revenues 2018-2023

3 PRODUCT REVIEW

This section contains DNV's review findings of CLOU's liquid cooling (Aqua-C) and air cooling (Aero-C) BESS systems, including BESS technical specifications, BESS performance, and thermal management system design.

3.1 CLOU BESS Overview – Aero-C

CLOU's 3 MWh air cooling BESS DC system, herein referred as Aero-C, is designed for large and medium sized energy storage power stations. Aero-C consists of following components:

- **Batteries** – Aero-C contains 8 battery racks, each of which has 21 modules and a control box. Each battery module has 20 cells connected in series (1P20S). The rated cell capacity is 280 Ah. Figure 3-2 shows the interior layout of the Aero-C.
- **Battery Management System** – hierarchical battery management structures include BAMS (Battery Array Management System), BCMS (Battery Cluster Management System), BMU (Battery Management Unit), and EMMU (Environmental Monitoring Management Unit).
- **Switch and communication panels** – including the Central Control Panel
- **Fire suppression system (FSS)** – including aerosol fire extinguishing agent, gas detectors, ventilation system, and water spray system, etc.
- **Heating, Ventilation, and Air Conditioning (HVAC)** – including 4 air conditioners with cooling capacity of 5 kW each.
- **Auxiliaries** – such as lighting system, grounding system etc.

Figure 3-1 shows the interior view and main components of Aero-C. The architecture is congruent with similar air-cooled BESS products in the market.

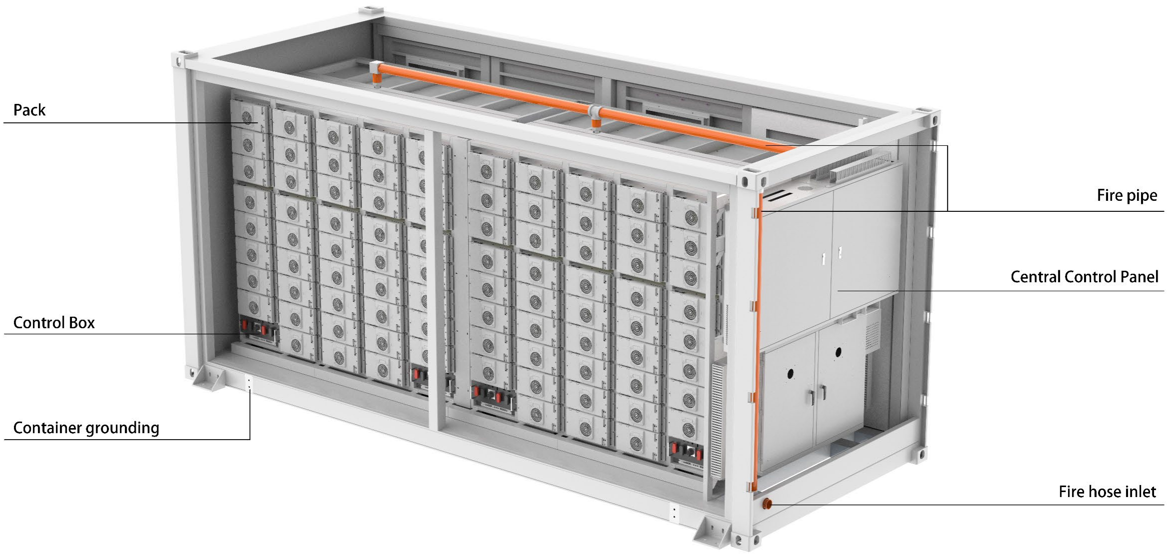


Figure 3-1 Interior view of Aero-C BESS system [4]

Figure 3-2 and Figure 3-3 illustrate Aero-C's mechanical layout and electrical single-line diagram (SLD). The SLD shows a set of eight (8) racks, each with a string of twenty-one (21) modules.

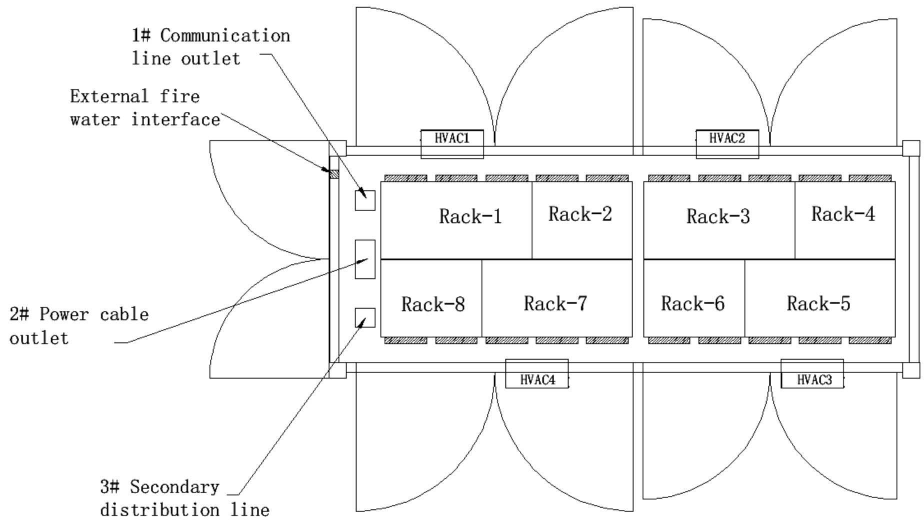


Figure 3-2 Layout of Aero-C

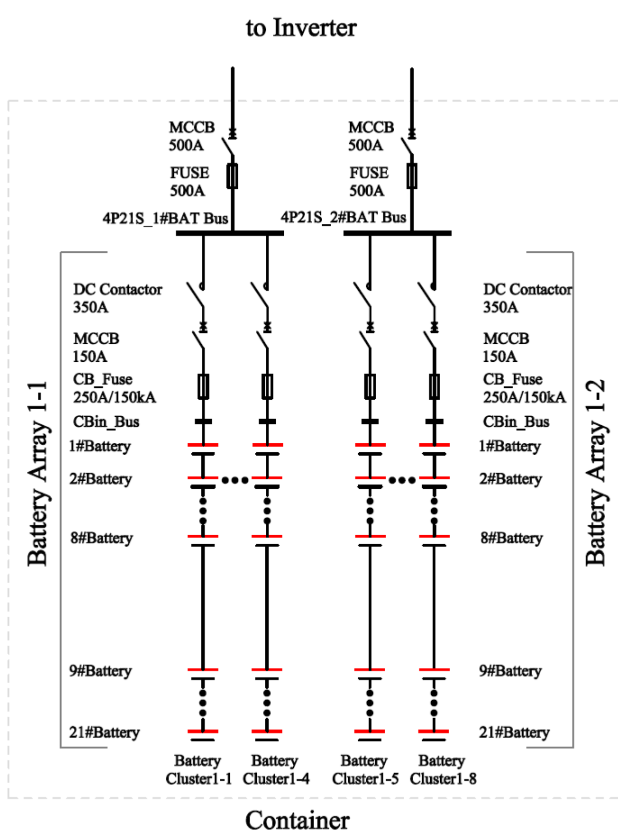


Figure 3-3 Single line diagram of the Aero-C

The system parameters of Aero-C are detailed in Table 3-1 [5].

Table 3-1 Aero-C system specifications

Parameter	Specification
Rated energy	3,010.56 kWh
Max. charge/discharge power	903.17 kW (0.3P)
Nominal DC voltage	1,344 V
DC voltage (full power)	1,113-1,480 V
Auxiliary power supply	480/277 Vac, 60 Hz
SOC calculation accuracy	± 3%
SOH at end of life (EoL)	60%
Operating temperature	-20 °C – 45 °C
Operating humidity	≤ 95% RH, no condensation
Altitude	< 3,000 m
Noise	< 75 dB(A) @ 1m
Protection grade	NEMA 3R / IP54
Corrosion-proof grade	C4 (EN ISO 12944)
Snow/ice loads	10 lb/sqft
Wind loads	115 mph
Seismic level	Meet the requirement of IEEE 693 standard high seismic level
External communication interface	Ethernet (copper and fibre)
Dimensions (W*D*H)	6,058*2,438*2,896 mm
Design life	20 years
Weight	≤ 34 tonnes
Transportation	Fully populated with battery modules

3.2 CLOU BESS Overview – Aqua-C

CLOU's 3.73 MWh liquid cooling BESS DC system, herein referred as Aqua-C, is designed for large and medium-sized energy storage power stations. Aqua-C, of which the interior view is illustrated in Figure 3-4, is made up of following critical components:

- **Energy Storage batteries** – rated at 280 Ah, supplied by REPT or Hithium. DNV notes that battery cells used by a single BESS system must be provided by one specific supplier. No BESS system uses mixed cells which are provided by different suppliers. The system contains 10 battery racks, each of which contains eight 1P52S battery modules, and a control box.
- **Battery management system (BMS)** – made up of hierarchical battery management units at different levels, including BAMS, BCMS, BMU, and EMMU.
- **Central control panel (CC panel)** – including AC Distribution Box, DC Junction Cabinet, Integrated Control Module, etc.

- **Fire suppression systems (FSS)** – uses aerosol as fire extinguishing agent, and equipped with gas detectors, ventilation system, and water spray system.
- **Liquid cooling system** – One liquid cooling unit with cooling capacity of 50 kW. The coolant used in Aqua-C is mixture of 50% ethylene glycol and 50% water, which is typical chemicals and composition used in liquid cooled BESS.
- **Auxiliaries** – such as alarms, chillers, pumps etc.

Aqua-C implements all-in-one design and is non-walk-in BESS system, which is typical design for BESS systems. The BESS system does not couple power conversion system (PCS) by default. Aqua-C has similar topology and control strategy as Aero-C except the differences of the energy capacities and cooling systems and fire suppression systems (FSS). The architecture of the Aqua-C is congruent with other liquid cooled BESS products in the market.

Figure 3-4 and Figure 3-5 illustrate Aqua-C's mechanical layout.

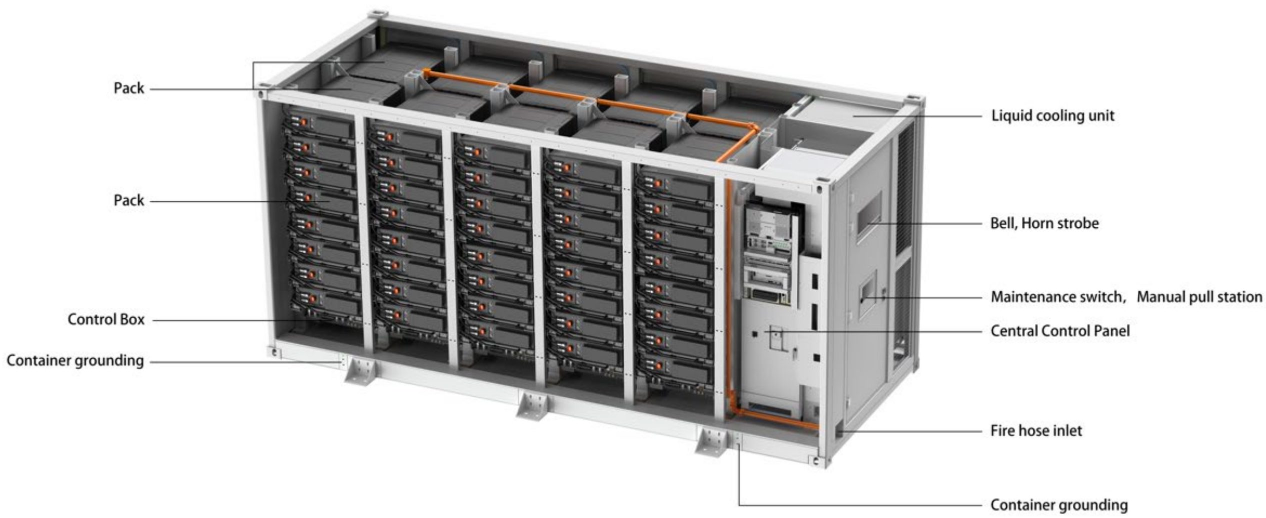


Figure 3-4 Interior view of Aqua-C BESS system

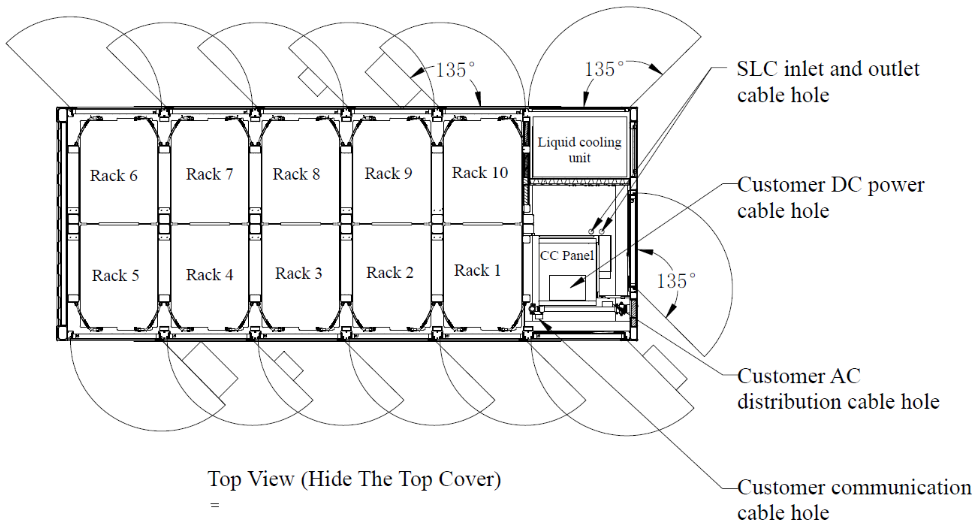


Figure 3-5 Layout of Aqua-C

The system parameters of Aqua-C are detailed in Table 3-2 [6].

Table 3-2 Aqua-C system specifications

Parameter	Specification
Rated energy	3,727 kWh
Max. charge/discharge power	1,863 kW (0.5P)
Nominal DC voltage	1,331.2 V
DC voltage (full power)	1,102.4 – 1,476.8 V
Auxiliary power supply	480 Vac, 60 Hz
SOC calculation accuracy	± 3%
SOH at end of life (EoL)	60%
Operating temperature	-30 °C – 50 °C
Operating humidity	≤ 95%, no condensation
Altitude	< 2,000 m
Noise	< 75 dB(A) @ 1m
Protection grade	NEMA type 3R / IP55
Corrosion-proof grade	C4 (EN ISO 12944)
Snow/ice loads	80 lb/sqft, customisable
Wind loads	147 mph, customisable
Seismic level	Meet the requirement of IEEE 693 standard high seismic level, customisable
External communication interface	Ethernet (copper and fibre)
Dimensions (W*D*H)	6,058*2,438*2,896 mm (20 ft container)
Design life	20 years
Weight	≤ 38 tonnes
Transportation	Fully populated with battery modules

3.3 System performance overview

The system level performance test includes charge and discharge capacity, RTE test, and temperature rise for three consecutive cycles, with rest time unknown between cycles [7]. DNV notes that the test report provided by CLOU is project specific, which may lead to differences in performance if operating conditions vary in other projects.

3.3.1 Aero-C performance testing

Table 3-3 shows the energy and RTE of three tested cycles.

Table 3-3 Average energy and RTE of Aero-C of three operating cycles

Cycle number	Rated energy/kWh	Charge energy/kWh	Discharge energy/kWh	RTE
1	3010.6	3191.9	3038.8	95.2%
2	3010.6	3246.0	3061.5	94.3%
3	3010.6	3248.2	3075.3	94.7%
Average	/	3228.7	3058.5	94.2%

Table 3-4 shows the ranges of temperature within a single cell at the end of charge and discharge.

Table 3-4 Temperature ranges of the single cell within Aero-C during system level test

Cycle number	Charge end temperature range	Discharge end temperature range
1	4 °C	4 °C
2	4 °C	4 °C
3	4 °C	4 °C
Average	4 °C	4 °C

Table 3-3 indicates that the average discharge energy exceeds the rated energy, and the average RTE exceeds the design criteria (94%). The RTE shown in Table 3-3 are measured for DC battery only. DNV notes that the RTE can vary depending on operating and environmental conditions. Furthermore, the RTE measured from AC side is lower than that from DC side due to additional loss through PCS and AC auxiliaries.

The temperature variations during three cycles of charge and discharge are maintained within 4°C by the thermal management system and BMS. DNV looks favourably on Aero-C's performance in terms of energy, RTE, and system temperatures in project scenarios in which 0.25P rate is used.

3.3.2 Aqua-C performance testing

Table 3-5 shows the energy and RTE of three tested cycles.

Table 3-5 Average energy and RTE of Aqua-C of three operating cycles

Cycle number	Rated energy/kWh	Charge energy/kWh	Discharge energy/kWh	RTE
1	3727.36	3970.0	3753.8	94.55%
2	3727.36	4055.2	3815.6	94.09%
3	3727.36	4062.0	3829.1	94.26%
Average	/	4029.1	3799.5	94.3%

Table 3-6 shows the ranges of temperature within a single cell at the end of charge and discharge.

Table 3-6 Temperature ranges of the single cell within Aqua-C during system level test

Cycle number	Charge end temperature range	Discharge end temperature range
1	2.2 °C	1.7 °C
2	2.0 °C	1.8 °C
3	2.3 °C	1.9 °C
Average	2.2 °C	1.8 °C

Table 3-5 indicates that the average discharge energy exceeds the rated energy, and the average RTE exceeds the design criteria (94%). The RTE shown in Table 3-5 are measured for DC battery only. DNV notes that the RTE can vary depending on operating and environmental conditions. Furthermore, the RTE measured from AC side is lower than that from DC side due to additional loss through PCS and AC auxiliaries.

The temperature variations during three cycles of charge and discharge are maintained within 3°C by the thermal management system and BMS, which is typical for BESS operating at 0.5P. DNV looks favourably on Aqua-C’s performance in terms of energy, RTE, and system temperatures in project scenarios in which 0.5P rate is used.

3.3.3 Degradation performance

The degradations of Aqua-C which use Hithium and REPT’s 280 Ah cells is simulated. As illustrated in Figure 3-6 [8] [9], it is expected to take 15 and 20 years for REPT and Hithium 280 Ah cells to reach 70% SOH, respectively, assuming the cells operate at 0.5P, 1 cycle per day at ambient temperature between 20-35 °C. DNV reminds to aware of the difference between the two cells.

However, the degradation of system may be different from the simulations of cells due to its characteristics and working conditions. No degradation performance data was provided for the review.

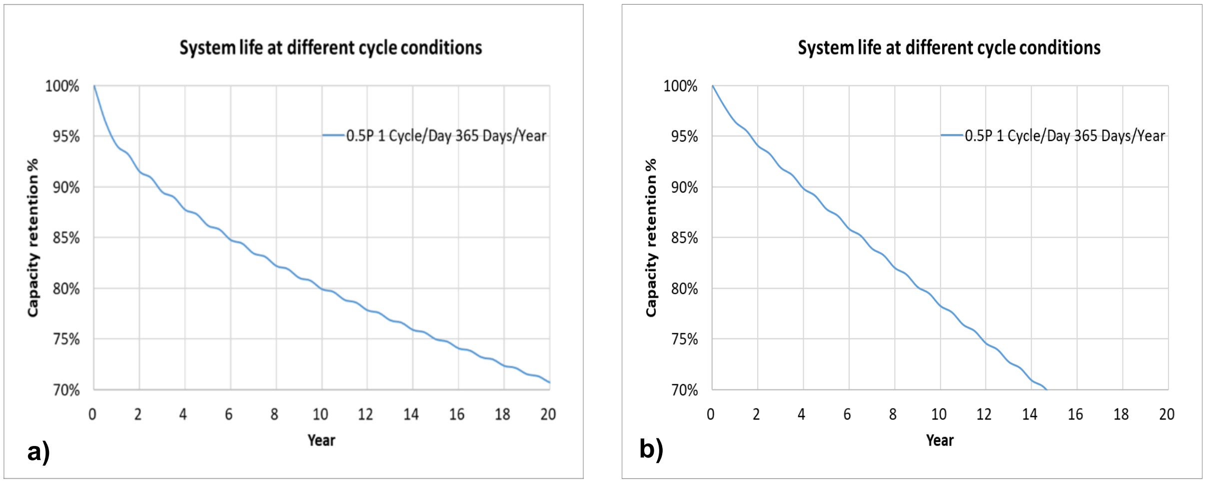


Figure 3-6 Degradation curves of a) Hithium's 280 Ah cells; b) REPT 280 Ah cells

3.4 Thermal management evaluation

Both Aero-C and Aqua-C are equipped with thermal management systems, of which the primary function is to maintain the cell temperature within its target temperature range. The cell temperature is evaluated by the BMS in every 40 seconds and commands will be sent to the thermal management system subsequently to maintain temperature difference within 10°C. DNV reviewed the thermal management systems of Aero-C and Aqua-C separately in the following aspects:

- thermal load calculation
- air duct/cooling pipe design
- thermal simulation analysis by computational fluid dynamics (CFD)

3.4.1 Aero-C thermal management design

3.4.1.1 Thermal load calculation

CLOU calculated heat energy released from all 168 battery modules within a system at the beginning of life (BOL) and the end of life (EOL). The power rate at which Aero-C operates through its life is 0.25C. DNV notes that CLOU has made following assumptions through these calculations [10]:

- CLOU assumed that all loss of energy calculated from the system efficiency is fully attributed to the heat release, which DNV considers reasonable.
- At the BOL condition, CLOU assumed an efficiency of 95.5%. At the EOL condition, CLOU assumed that the SOH and RTE are 67.9% and 94.28%, respectively
- CLOU decided to use the heat energy release at BOL as design parameter and the benchmark of design requirement, because the heat release at BOL is higher than that at EOL. Nevertheless, CLOU must ensure that HAVCs operate in full power at EOL. The guidance on HAVCs maintenance, warranty terms and replacement must be provided to CLOU's customers. DNV opines that such design consideration is appropriate. The total heat load from all battery modules is 16.93 kW at a 0.25P rate.

CLOU's thermal design instructions document demonstrates the consideration of heat sources other than cells, such as fans, control box copper bus bars and so on. DNV opines that the design calculations of the thermal management system for Aero-C are appropriate.

3.4.1.2 Air duct design

Aero-C's air duct design has the following features:

- The supply of the air applies top-in and bottom-out design. When the cold air is fed into the air inlet on the top of racks, module fans will force cold air to flow through modules.
- As depicted in Figure 3-7 a), each cabinet is shared by two battery racks, each of which contains 21 modules. The cabinets are installed back-to-back. Figure 3-8 a) demonstrates the animated interior view of the system, in which the locations of four HVACs are illustrated.
- The gap between sides of each battery rack and the width between back of cabinets are 32.5 mm and 65 mm, respectively.

- Each HVAC is responsible for supplying cold air and discharging hot air from the battery rack on which the HVAC is installed and the battery rack behind it. For example, as shown in Figure 3-8 b), HVAC 1 conducts thermal control for rack 1 and rack 8.

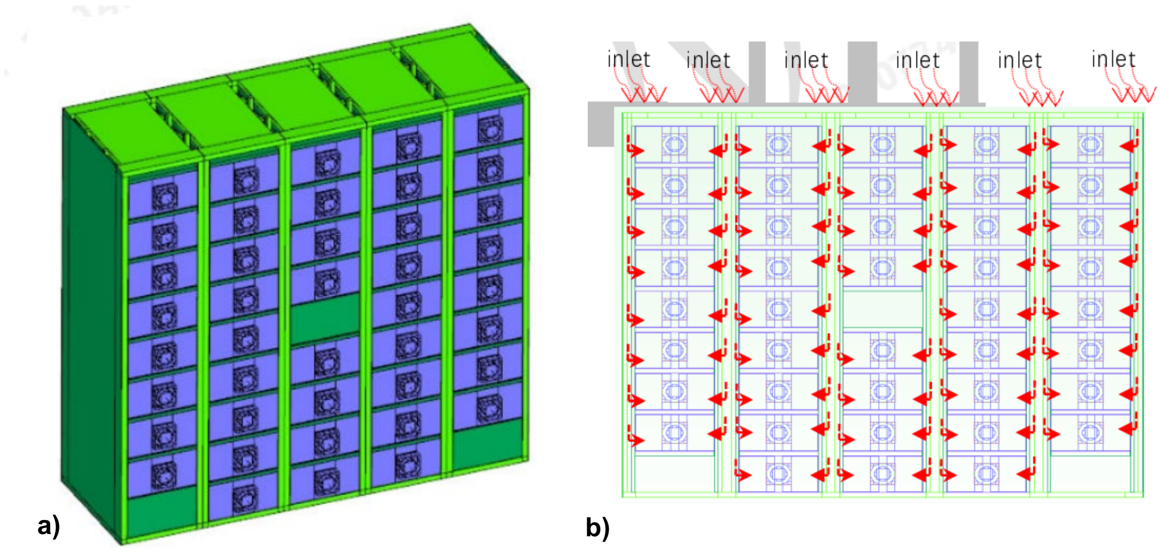


Figure 3-7 a) animated view of a single cabinet, which is made up of two 1P21S battery racks; b) front view of the cabinet where the air inlet and airflow routes are indicated

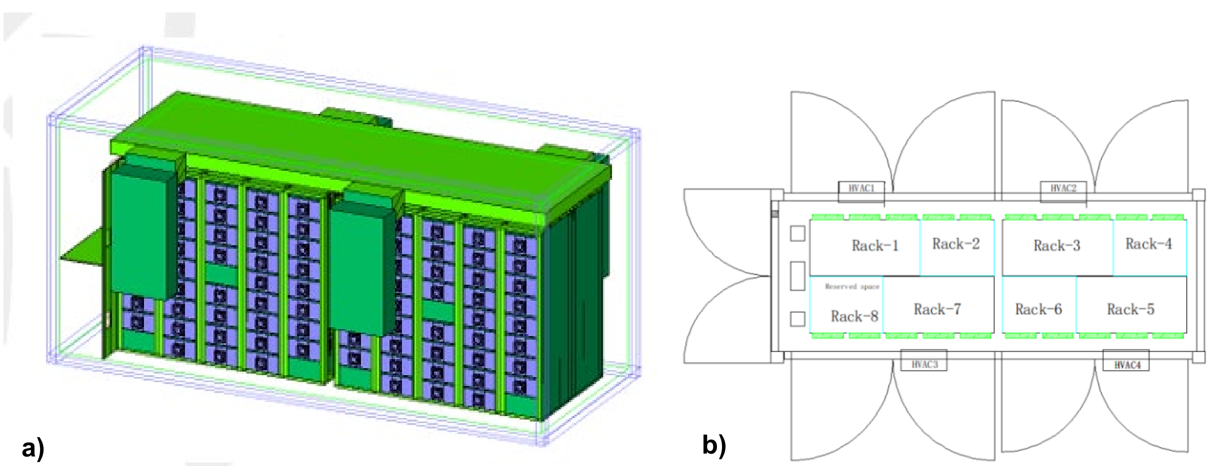


Figure 3-8 a) animated interior view of whole Aero-C; b) top view of the Aero-C with the locations of battery racks and HVACs indicated

3.4.1.3 Thermal simulation analysis

DNV reviewed a summary of CFD simulation analysis which exhibits the expected cooling to be achieved in Aero-C [11]. The simulation is based on following input assumptions and design requirements:

- The cooling requirements of 0.25P is 16.93 kW. The EOL scenarios are not simulated because the thermal energy at EOL is lower than that at BOL.
- The total of other heat loss released within the system such as fans, control box copper bus bars and etc. is 4 kW.
- The thermal management system is required to maintain temperature variation (T_{max} – T_{min}) within 10 K.

The simulation is performed on 4 cases as described below:

- Case 0: Simulation of single battery module at a 0.25P rate and 25 °C ambient temperature
- Case 1: Simulation of Aero-C system at a 0.25P rate and 30 °C ambient temperature
- Case 2: Simulation of Aero-C system at a 0.25P rate and 40 °C ambient temperature
- Case 3: Simulation of Aero-C system at a 0.3P rate and 45 °C ambient temperature

DNV performed detailed review on simulation of single battery module (Case 0) and the one with the most severe conditions, which is Case 3.

The simulation model of the Case 0 is illustrated in Figure 3-9.

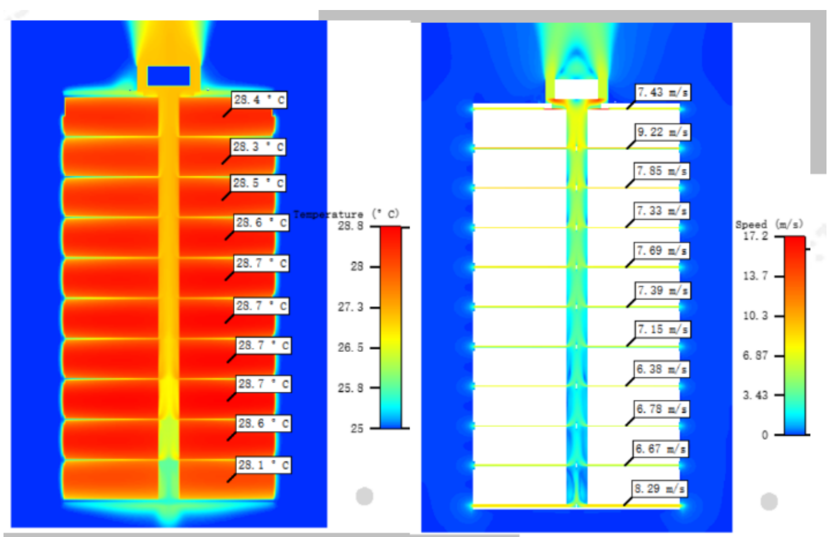


Figure 3-9 CFD model (top view) of Aero-C battery modules

The following conclusions can be drawn based on the simulation results of the Case 0:

- At 0.25P operation, the temperature range across battery modules is 28.1 – 28.7 °C, which leads to the maximum temperature variation of 0.6 K. The design requirement (within 10K) is satisfied.
- At 0.3P operation, the temperature range across battery modules is 29.1 – 30 °C, which leads to the maximum temperature variation of 0.9 K. The design requirement (within 10K) is satisfied.

Figure 3-10 illustrates the temperature distribution across the Aero-C system in case 3.

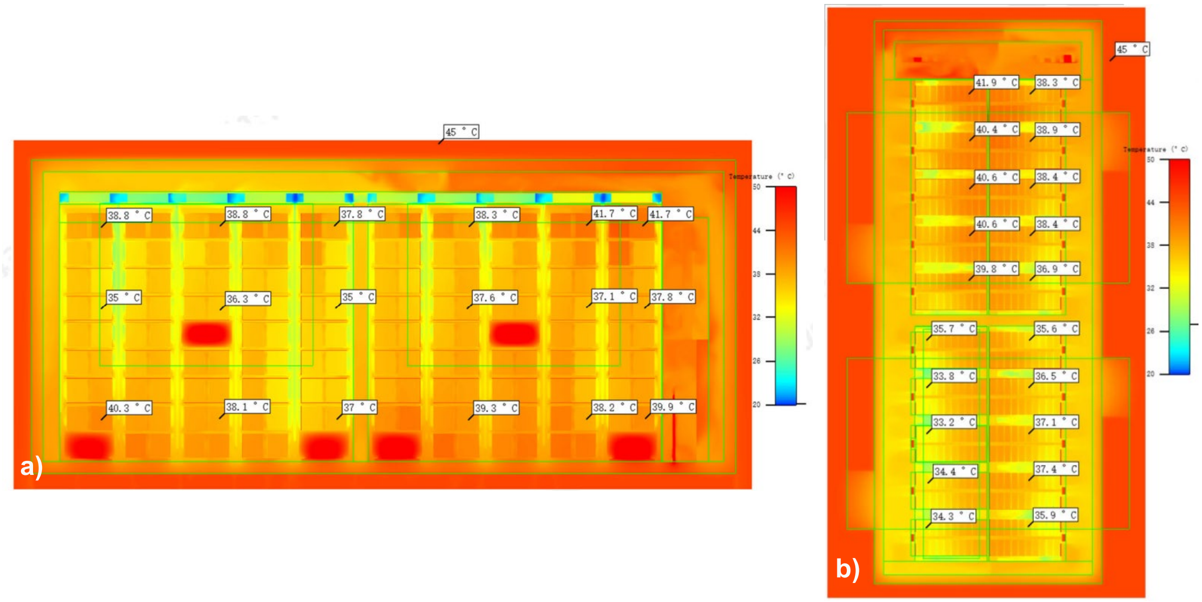


Figure 3-10 Case 3 CFD simulation result of Aero-C; a) front view; b) top view

For the 0.3P system operating at 45 °C ambient temperature, the temperature range across container is 33.2 – 42.9 °C, with maximum temperature difference is 9.7K. DNV notes that higher temperature mainly occurs in battery racks near the central control box. The simulation concluded that the temperature variation of 9.7K across the container met design requirement, however in real life operation the temperature variation across the BESS system could be more significant. CLOU can further validate the CFD results by performing real life test at 45 °C ambient temperature and cross comparing both simulated and experimental results.

3.4.2 Aqua-C thermal management design

3.4.2.1 Thermal load calculation

DNV reviewed the thermal load calculation provided by CLOU, which addresses both internal and external loads managed by the chiller system [12]. The calculation was performed under the following conditions and assumptions, although it should be noted that the document did not specify whether the calculation was based on the Beginning of Life (BOL) or End of Life (EOL) condition:

- All 80 battery modules in the Aqua-C container complete one cycle operation of charge and discharge at a 0.5P rate. The calculation accounts for varying heat loss at different States of Charge (SOC) during both charge and discharge phases.
- Initial conditions at the beginning of the charge cycle were set at 25 °C for cell temperature and 20 °C for chiller supply liquid temperature.
- Heat leakage through all six surfaces of the container was considered, assuming an external ambient temperature of 50°C and heat radiation from the outer surface of the container at 70 °C.
- Heat losses from control boxes and DC-DC modules within the container were included in the calculation.

According to the document, the calculation indicates that a single chiller with a cooling capacity of 45kW at 50°C can maintain the battery cell temperature below 37.8°C. It should be noted that DNV has not received or reviewed the basis for the assumption, or the thermal control scheme of Aqua-C, for maintaining the cell and coolant at the initial temperature assumed in the calculation. Nevertheless, DNV considers the cooling capacity of the chiller to be within the expected range for the nominal electrical storage capacity of Aqua-C.

The thermal management system's performance was evaluated also under extreme low-temperature conditions. At an external ambient temperature of -30°C, which represents the minimum specified operating condition, the 16kW Positive Temperature Coefficient (PTC) heater demonstrated the capability to elevate the temperature of both the battery cells and coolant to above 10°C. This temperature increase was achieved within 18.2 hours, enabling the system to attain normal charge and discharge functionality. The -30°C starting point was applied uniformly to the external environment, battery cells, and coolant to simulate a worst-case scenario.

3.4.2.2 Cooling pipe design

The thermal management system employs a circulating coolant through a piping network that extends to the module level. As depicted in Figure 3-11, each cold plate is designed to service four battery modules, facilitating heat transfer from the battery modules to the coolant. Subsequently, the heated liquid is returned to the chiller for temperature reduction. This configuration allows for efficient thermal management across the battery system, ensuring optimal operating conditions for the modules.

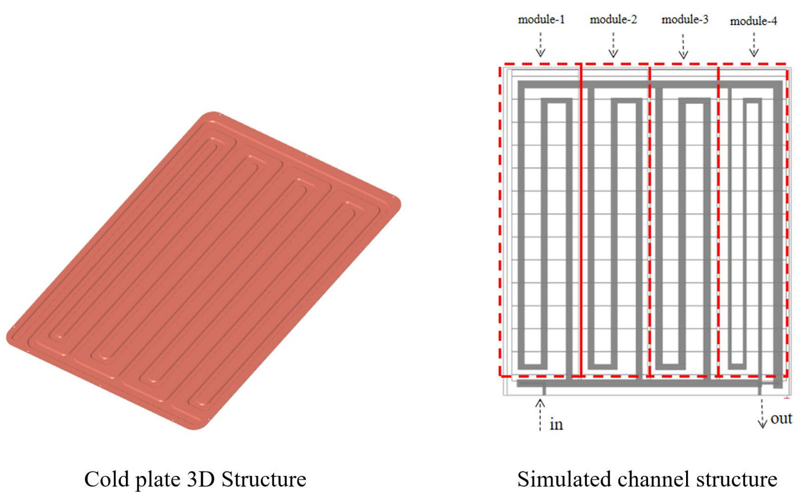
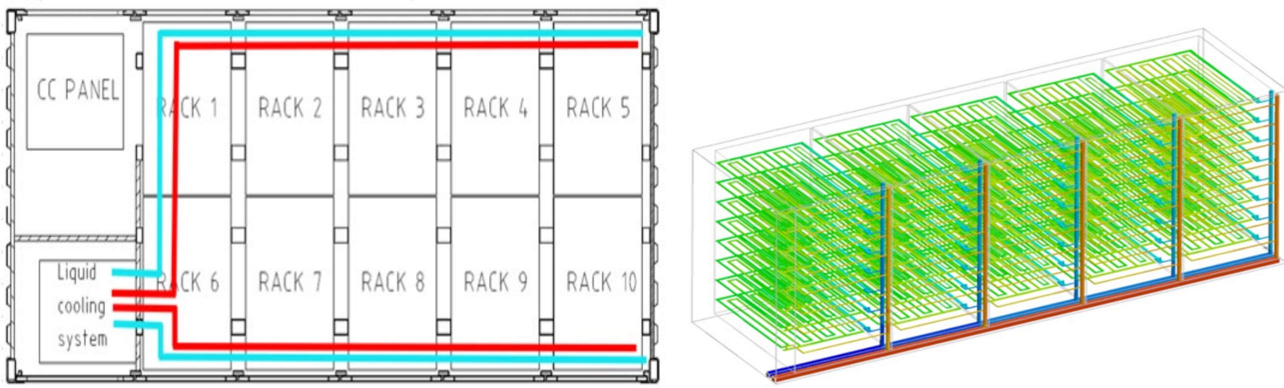


Figure 3-11 Module Cold Plate Structure Diagram

As shown in Figure 3-12 a), The thermal management system utilizes a chiller to pump coolant through a primary piping network. This network is installed at the base of the enclosure and distributes the coolant to five individual racks. Figure 3-12 b) provides a detailed illustration of the secondary and tertiary distribution piping, which channels the coolant from the primary pipes to the cold plate of each battery module. This tiered distribution system ensures efficient and uniform cooling across all battery components within the enclosure.



a) **b)**

Figure 3-12 a) Primary pipeline routing diagram; b) Isometric drawing of liquid circulation network

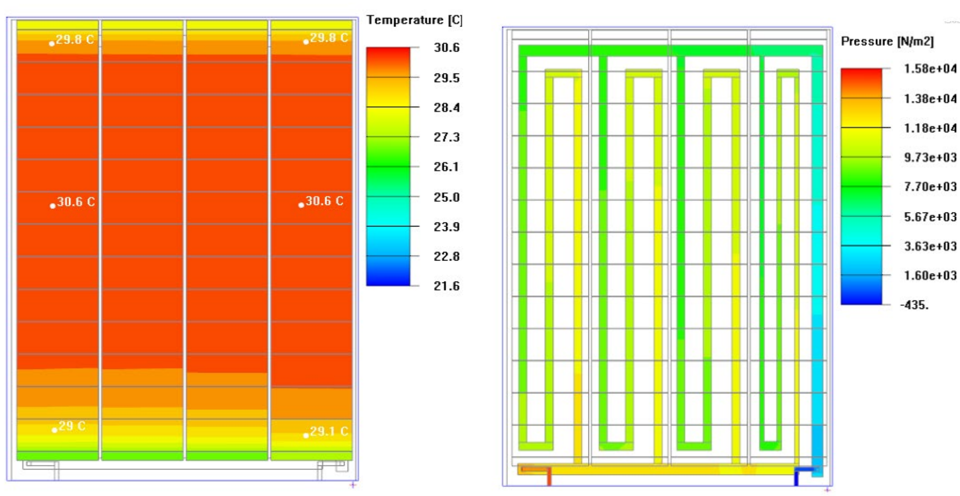
DNV has not received and reviewed the detail information on quantity and components of the cooling system.

DNV has not received and reviewed the measures to mitigate the risks of introducing conductive fluid near the batteries and electronics due to leak.

3.4.2.3 Thermal simulation analysis

DNV has reviewed CFD simulation analysis on a single battery module of Aqua-C. [13] The simulation is based on following input assumptions and design requirements:

- At 0.5C operation, heat generation from a single cell charging and discharging is 13.44 W.
- Inlet liquid temperature is 20 °C, with flow rate of 4.68 L/min.



a) b)

Figure 3-13 Module CFD analysis result - a) temperature distribution; b) pressure distribution

As depicted in Figure 3-13, the resulting temperature range across the battery module is 27.7 – 29.4 °C, which leads to the maximum temperature variation of 1.7 K. The maximum temperature is within typical optimal cell temperature range, and the temperature variation is within the acceptable range.

DNV has not received and reviewed sufficient information on CFD simulation on a rack- or a container-level.

4 BATTERY COMPONENT EVALUATION

This section of the report focuses individually on 280 Ah cell supplied by two suppliers, namely REPT and Hithium, composing of battery module and rack products. The evaluation is based on a desktop review of the product specification sheets and performance test results. DNV has conducted bankability review for REPT and Hithium's 280 Ah cells, therefore the contents of sections 4.1 and 4.2 are primarily derived from those bankability reports performed by DNV, of which the document numbers are as follow:

- REPT 280 Ah cell bankability review: 10306655-INBA-R-01
- Hithium 280 Ah cell bankability review: 10336911-INBA-R-01

4.1 Battery review - REPT 280 Ah cell

DNV has reviewed technical specifications, electrochemical performance, and safety of REPT's 280 Ah cell. The technical specifications are provided in Table 4-1.

Table 4-1 Technical specifications of REPT 280 Ah cell

Item	Specifications	Comment
Cell Model	CB71173204EB-280Ah	
Nominal Capacity	280 Ah	25 ± 2°C, 0.5 P/0.5 P
Nominal Voltage	3.2 V	
Operating Voltage	2.5–3.65 V 2.0–3.65 V	0°C < T < 55°C -30°C ≤ T ≤ 0°C
Standard Discharging Power	448 W	25 ± 2°C
Maximum Continuous Discharging Power	896 W	25 ± 2°C, SOC ≥ 20%
Maximum Discharging Power	1,792 W	@ 60 sec, SOC ≥ 20%
Standard Charging Power	448 W	25 ± 2°C
Maximum Continuous Charging Power	896 W	25 ± 2°C, SOC ≤ 80%
Maximum Charging Power	1,792 W	@ 60 sec, SOC ≤ 80%
Operating Temperature	0°C < T ≤ 55°C -30°C ≤ T ≤ 60°C	Charge Discharge
Storage Temperature	-30°C – 60°C	
Typical Dimension (L*W*H, mm)	174 ± 0.5 * 71.7 ± 0.5 * 206.8 ± 0.6	Height includes electrode terminals
Cell Weight	5.5 ± 0.15 kg	
Energy Density	166 Wh/kg, ~352 Wh/L	
ACR (1 kHz)	≤ 0.30 mΩ	25~50% SOC
Cycle Life	Cycle number ≥ 6000 times	Cycle number under SOC 80%

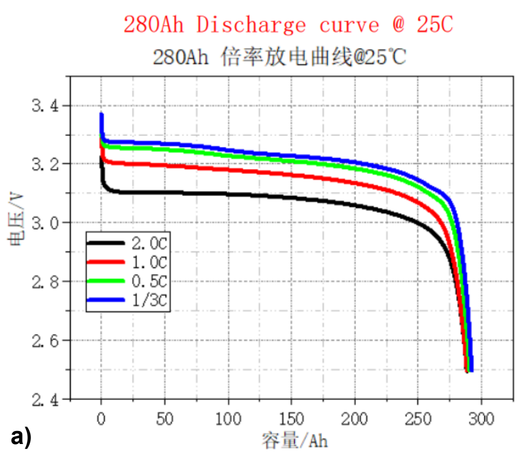
4.1.1 Cell electrochemical performance

Based on the information available, DNV reviewed REPT's 280 Ah cell performance in following aspects:

- discharge C-rate performance
- high/low temperature discharge performance
- charge and discharge curve
- cycle life/capacity retention
- calendar life

DNV's opinions in this section are fully dependent on the documents provided by CLOU/REPT. REPT has engaged DNV to perform third-party performance test according to DNV's Battery Scorecard. DNV encourages CLOU to request the test report from REPT.

In the C-rate performance test, the cell was charged at 25°C by constant current (CC) of 1.0C to 3.65 V and constant voltage of 3.65 V until current drops to 0.05C, followed by discharge with 0.33C, 0.5C, 1.0C, and 2.0C. Figure 4-1 depicts discharge curves and temperature rise curves of REPT 280 Ah cell at different C-rates. The numerical results are summarised in Table 4-1.



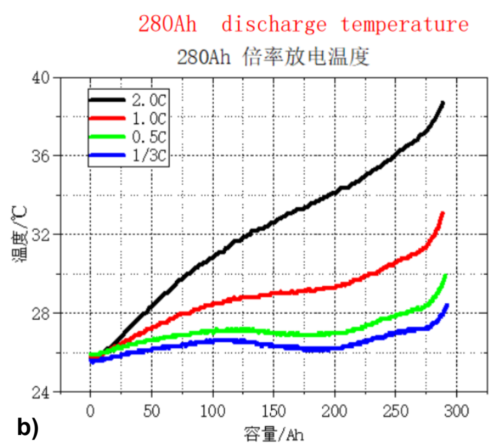


Figure 4-1 a) discharge curves at various C-rates; b) temperature rise curves at corresponding C-rates

Table 4-2 Discharge capacity, energy, and temperature rise at various C-rates

Discharge rate	0.33C	0.5C	1.0C	2.0C
Discharge capacity/Ah	287.921	286.701	287.26	289.262
Discharge energy/Wh	918.033	907.804	898.412	880.719
Temperature rise/°C	3.3	4.5	8.25	13.5

Table 4-1 illustrates that discharge capacities of REPT's 280 Ah cell exceeded its rated capacity when discharge at 0.33C, 0.5C, 1.0C, and 2.0C. Figure 4-1 a) illustrates that the discharge curves are in typical shape for the LFP chemistry and there is no evident side reaction observed along discharge curves of all C-rates, which DNV looks favourably. Figure 4-1 b) depicts temperature rise during discharge by various C-rates and illustrates that the temperature rise becomes more significant as higher C-rate is used, which is a typical phenomenon because higher C-rate leads to higher reaction thermodynamics of the exothermic reaction during cell discharge. DNV notes that cell temperature exceeds the optimal operating temperature range, which is typically between 15 °C to 30 °C, when 1.0C and 2.0C are used. Therefore, it is essential to use REPT's 280 Ah cell with appropriately designed thermal management system and BMS to prevent overheating of cells.

Figure 4-2 depicts discharge curves and temperature rise at different temperatures include 25 °C, 55 °C, 0 °C, and -20 °C. The temperature range chosen by REPT for low/high temperature performance characterization is typical in the battery industry. The test procedures are as follow:

1) resting for 5 hours at 25 °C
2) charging the cell at 25 °C by constant current (CC) of 1C to 3.65 V and constant voltage of 3.65 V until current drops to 0.05C, followed by 30 minutes rest
3) the temperature chamber is set to target temperatures and resting the cell for various durations, i.e. 5 hours at 55 °C/25 °C, 10 hours at 0 °C, and 24 hours at -20 °C
4) discharging the cell by constant current of 1C until the voltage reaches 2.5 V at 55 °C/25 °C or 2.0 V at 0 °C/-20 °C.

The discharge and temperature rise curves are shown in Figure 4-2, and the data are tabulated in Table 4-2.

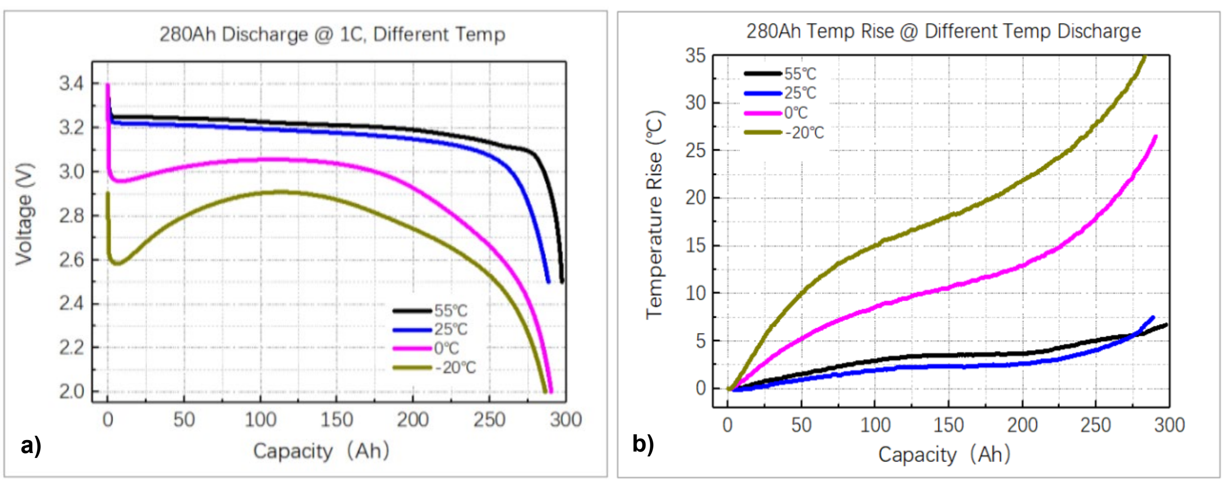


Figure 4-2 a) discharge curves at different temperatures; b) temperature rise curves at corresponding temperatures

Table 4-3 Discharge capacity, discharge energy, and temperature rise at different operating temperatures

Temperature (°C)	55	25	0	-20
Dis. Capacity (Ah)	297.3	288.5	290.4	286.4
Dis. Energy (Wh)	947.3	906.2	842.7	780.1
Temperature rise (°C)	6.7	7.5	26.5	36.3

Table 4-2 indicates that the discharge capacities of REPT's cell exceeded its rated capacity even at extremely low ambient temperature of -20°C. DNV opines that the REPT's cell exhibited better performance at low temperature in terms of discharge capacity compared to other LFP cells available in the market. However, it can be observed in Figure 4-2 a) that the discharge curves for 0°C and -20°C significantly deviate from the typical discharge curve as it is for 25°C, which is the sign of occurrence of unwanted side reactions. Furthermore, the electrochemical reaction becomes thermodynamically unfavorable at low temperature, which is indicated in Figure 4-2 b) that the temperature rise can go up to 36.3 °C. While these characteristics are typical for LFP chemistry, DNV notes that the Aero-C and Aqua-C are equipped with thermal management system and BMS, both of which adjust operating temperatures and allow cells to operate within its optimal temperature range.

The cycle life test, which is also known as the capacity retention test results performed at 25 °C and 45 °C are shown in Figure 4-3. The test procedures are as follow:

1) charging the cell by 1C constant current to 3.65 V & constant voltage until current reduces to 0.05C
2) resting the cell for 30 minutes
3) discharging the cell by 1C constant current to 2.5 V
4) repeating steps 1) – 3) until target number of cycles is reached.

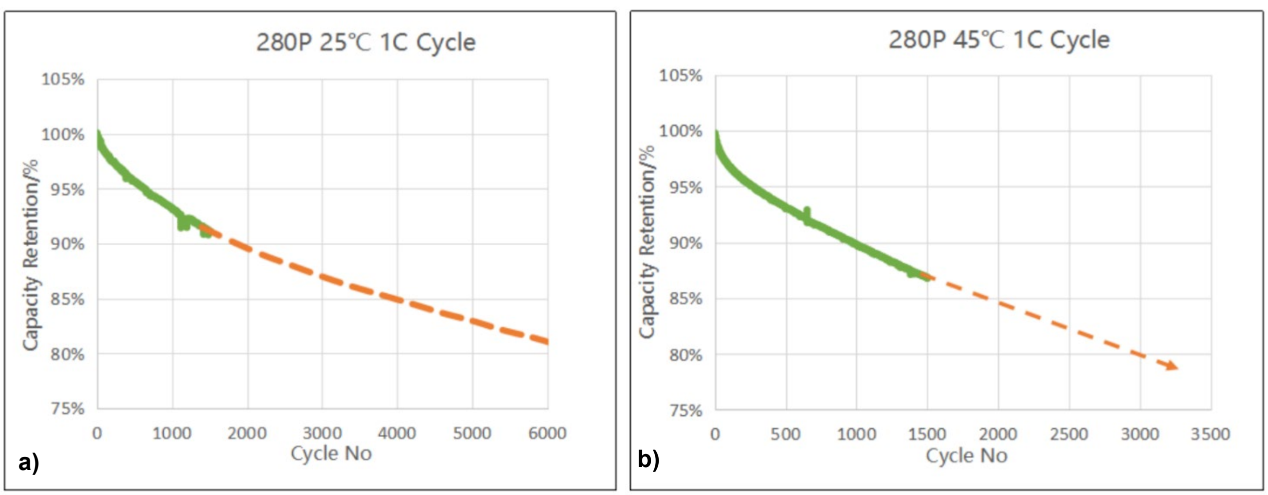


Figure 4-3 Capacity retention verses cycle numbers for a) 25°C and b) 45°C

DNV notes that Figure 4-3 a) and b) contain both test data (in green solid lines) and simulated data (orange dotted dash lines). According to the extrapolations based on the 1,500 cycles test data, it is expected that the cell will retain 80% of its initial capacity after more than 6,000 cycles at 25 °C / 1C condition, and 3,000 cycles at 45 °C / 1C condition respectively. DNV opines that it aligns with the industry expectation.

Figure 4-4 shows the calendar life or storage characterization of REPT's 280 Ah cell in a form of recoverable capacity ratio verses storage time in days. The test procedures are as follow:

1) charging the cell by 1C constant current to 3.65 V & constant voltage until current reduces to 0.05C

2) resting the cell for 30 minutes

3) the cell is stored at 100% SOC at 25 °C and 50% at 45 °C

4) recoverable capacity is measured on day 7, 14, 21, 28, and then every 30 days

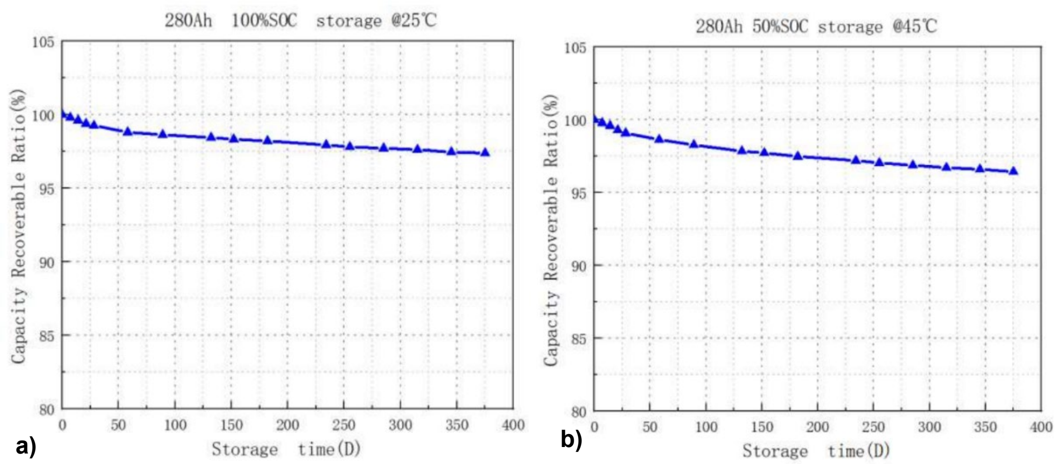


Figure 4-4 Recoverable capacity ratio versus storage time for a) 25 °C storage and b) 45 °C storage

Figure 4-4 indicates that REPT's 280 Ah cell achieves recoverable capacity of around 97.5% at 25 °C ambient temperature and 96% at 45 °C , which meets typical industry expectation.

4.1.2 Cell safety

REPT's 280 Ah cell has performed following safety tests, of which test conditions and pass criteria are according to Chinese national standard GB/T 31485 – 2015 and GB/T 36276 – 2018.

Table 4-4 Summary of internal safety tests which REPT's 280 Ah cell has passed

Test item	Test result	Pass/Fail
Overcharge	No fire and no explosion	P
Over discharge	No fire and no explosion	P
Short circuit	No fire and no explosion	P
Nail penetration	No fire and no explosion	P
Crush	No fire and no explosion	P
Hot box	No fire and no explosion	P
Drop	No fire and no explosion	P
Thermal runaway	No fire and no explosion	P

Figure 4-5 REPT's 280 Ah cells after different safety tests

4.2 Battery review - Hithium 280 Ah cell

DNV has reviewed technical specifications, electrochemical performance, and safety of Hithium's 280 Ah cell. The technical specifications are provided in Table 4-5. Hithium has engaged DNV to perform third-party performance test according to DNV's Battery Scorecard. DNV encourages CLOU to request the test report from Hithium.

Figure 4-6 Hithium's 280 Ah LFP cell

Table 4-5 Technical specifications of Hithium's 280 Ah LFP cell

Parameter	Specification
Type	LFP
Model	LFP71173207/280 Ah
Dimension	(71.65±0.5 mm) × (174.7±0.5 mm)×(207.11±0.5 mm)
Weight	5.43±0.20 kg (Including Enclosure)
Impedance (1KHz)	0.18±0.05 mΩ, 27% SOC
Typical capacity	280 Ah at (25±2) °C
Typical voltage	3.2 V
Typical energy	896 Wh
Operating voltage	2.5-3.65 V (cell temperature T>0 °C) 2.0-3.65 V (cell temperature T≤0 °C)
Shipping voltage	3.28 V to 3.30 V
Energy density	≥160 Wh/kg
Recommended SOC interval	SOC:10%～90%
Residual capacity loss	≤3.0%; Fresh cell after 3 months,25±2 °C, 27% SOC
Max continuous charging power	1P
Max continuous discharge power	1P
Operating temperature (discharge)	-30 °C to 60 °C
Operating temperature (charging)	0 °C to 60 °C

4.2.1 Cell electrochemical performance

The capacity retention of Hithium's 280 Ah cell under 0.33C, 0.5C, 1.0C, and 2.0C is plotted in Figure 4-7, and the numerical data are tabulated in Table 4-6.

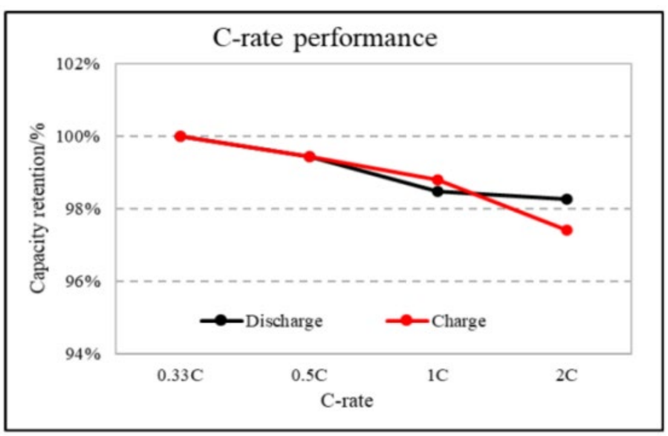


Figure 4-7 Capacity versus C-rate graphs of Hithium's 280 Ah cell

Table 4-6 Hithium's 280 Ah cell C-rate performance summary

C-rate	0.33C	0.5C	1C	2C
Charge capacity retention, %	100.0%	99.44%	98.79%	97.42%
Discharge capacity retention, %	100.0%	99.44%	98.47%	98.25%

DNV is not able to comment on the discharge capacities of the cell as the y-axis in Figure 4-7 shows capacity retention instead of discharge capacity. DNV notes that it is common for the actual charge and discharge capacity to exceed cell rated capacity, therefore Hithium may not have used 280 Ah as the reference for 100% SOC.

DNV reviewed the high and low temperature performance test of Hithium 280 Ah cells. This test was performed on two 280 Ah cells to verify the consistency. The capacity retention versus temperature and the numerical test data are shown in Figure 4-8 and Table 4-7, respectively.

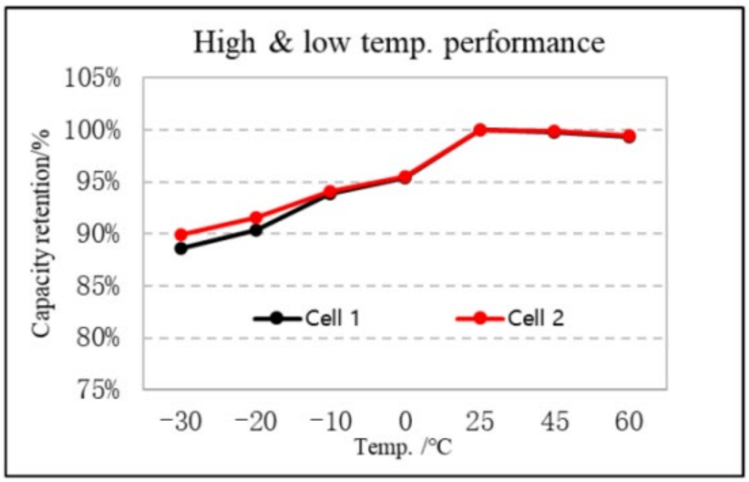


Figure 4-8 Capacity retention versus temperature graphs for Hithium's 280 Ah cell

Table 4-7 Hithium's 280 Ah cell low/high temeprature performance summary

Temperature (°C)	-20	-10	0	25	45	60
Retention, Cell 1	90.33%	93.87%	95.35%	100%	99.76%	99.31%
Retention, Cell 2	91.51%	94.08%	95.50%	100%	99.86%	99.49%

DNV notes that Hithium's 280 Ah cell can retain 100% capacity when it is discharged at 25°C, 45°C, and 60°C. Prolonged operation at temperature outside the optimal temperature range could accelerate the degradation of LFP cells, therefore Hithium's cell should be used with appropriately designed thermal management system and BMS. When temperature reduces below 0°C, it is expected that the cell performance deteriorates, which is reflected in Figure 4-8 that the capacity retention is lower than 100%. DNV is not able to comment conclusively on the low temperature performance, as neither discharge capacity nor discharge curves were provided for review.

Hithium provided cycle life results of 280 Ah battery cell tested under 25°C, as exhibited in Figure 4-9 a). The capacity retention is approximately 86% after 4000 cycles of charge and discharge at 0.5C. The capacity retention test is an ongoing and prolonged test, which provides clearer sense of cell degradation trend as the cell charged and discharged for more cycles. Therefore, DNV advises CLOU to request the updated capacity retention testing results from Hithium in regular basis. Figure 4-9 b) depicts the calendar life test of 280 Ah cell which was performed at 100% SOC at 25°C. The SOH versus time graph indicates that the cell retains above 70% SOH after 30 years of storage.

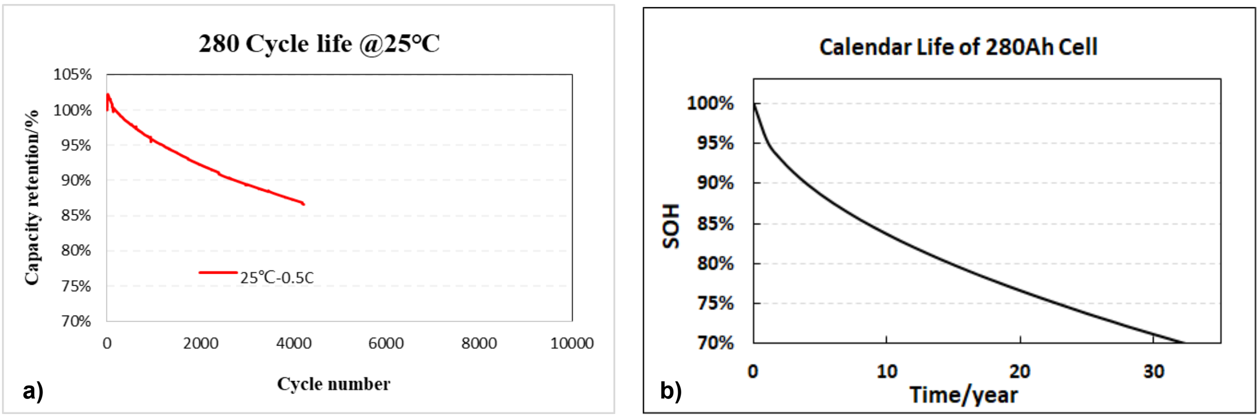


Figure 4-9 a) Cycle life performance; b) calendar life performance

4.2.2 Cell safety

DNV has not been provided an internal test report which concludes cell safety performance. However, Hithium's 280 Ah has obtained certificates and test reports which are mandatory in North America. The details of certificates and test reports are outlined in Section 5.1.

4.3 Aero-C battery module and rack

4.3.1 Battery module design and specifications

The battery module used in Aero-C is made up of twenty 280 Ah cells connected in series (1P20S). The battery module is equipped with a BMU, which monitors safety parameters associated to the module level and reports to the cluster level BCMS. The safety parameters include but are not limited to cell voltages, temperature, and cell balancing states in real time. Each module is equipped with a fan which is controlled by BMU. The module specification is outlined in Table 4-8.

Table 4-8 Tehnical specifications of Aero-C battery module

Item	Specification	Remark
Configuration	1P20S	
Rated capacity	280 Ah	25 ± 2°C
Rated voltage	64 V	
Rated energy	17.92 kWh @ 0.5 P	25 ± 2°C
Maximum discharge power	8.96 kW	
weight	125 kg	
Operating temperature	Charge: 0 – 45°C Discharge: -30 – 45°C	Recommended 25 ± 5°C

Storage condition	-20 - 45°C @ 40% SOC	Recommended 20 ± 5°C
Humidity	10 – 85% RH	Non-condensing
Dimensions (Depth x Width x Height)	D: 850 ± 3 mm (with cover) W: 428 ± 3 mm H: 227 ± 3 mm	

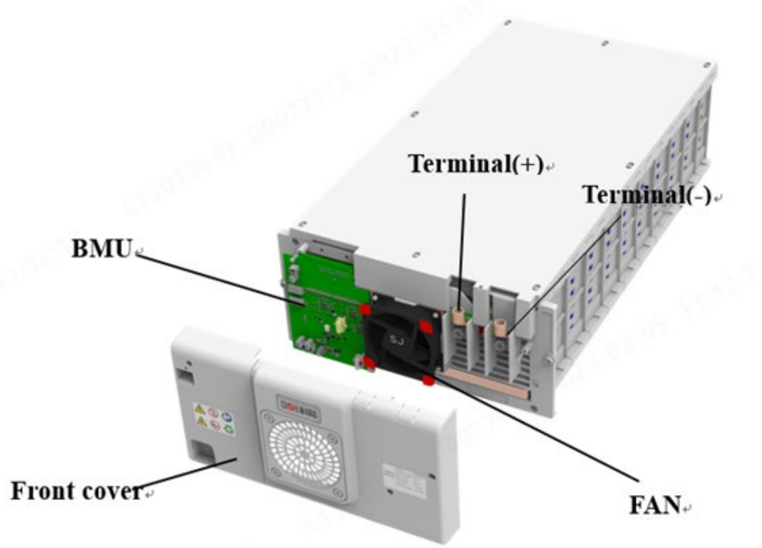


Figure 4-10 Aero-C battery module and its key components

4.3.2 Battery rack design and specifications

Each battery rack is made up of 21 battery modules in series according to 1P21S configuration. The battery rack is protected by the BCMS and control box. For the detailed functions of each component, refer to section 5.2. The battery rack specification is outlined in Table 4-9.

Table 4-9 Technical specifications of Aero-C battery rack

Item	Specification	Remark
Rated capacity	280 Ah	25 ± 2 °C
Rated voltage	1,344 V	
Rated energy	376.32 kWh @ 0.3 P	25 ± 2 °C
Maximum power	112.896 kW	
Recommended operating temperature	25 ± 5 °C	
weight	5,900 kg	
Humidity	10 – 85% RH	Non-condensing
Type of installation	Indoor	

Dimensions (Depth x Width x Height)	D: 855 mm (without modules) W: 1,518 mm H: 2,248 mm

Figure 4-11 Appearance of a single Aero-C battery rack

4.4 Aqua-C battery module and rack

4.4.1 Battery module design and specifications

The battery module used in Aqua-C is made up of fifty-two 280 Ah cells connected in series (1P52S). The battery module is equipped with a BMU, which monitors safety parameters associated to the module level and reports to the cluster level BCMS. The safety parameters include but are not limited to cell voltages, temperature, and cell equilibrium states in real time. Each module is equipped with a fan which is controlled by BMU. The module specification is outlined in Table 4-10.

Table 4-10 Technical specifications of Aqua-C battery module

Item	Specification	Remark
Configuration	1P52S	
Rated capacity	280 Ah	25 ± 2 °C
Rated voltage	166.4 V	
Rated energy	46.592 kWh @ 0.5 P	25 ± 2 °C
Maximum discharge power	23.296 kW	
weight	330 kg	
Operating temperature	Charge: 0 – 45 °C Discharge: -20 – 45 °C	Recommended 25 ± 5 °C

Storage condition	-20 - 45°C @ 40% SOC	Recommended 20 ± 5 °C
Humidity	10 – 85% RH	Non-condensing
Dimensions (Depth x Width x Height)	D: 1,070 ± 3 mm W: 810 ± 3 mm H: 264 ± 3 mm	

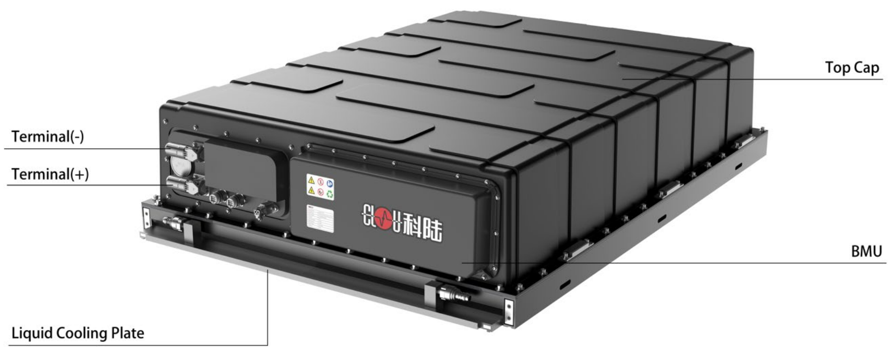


Figure 4-12 Apperance of Aqua-C battery module

4.4.2 Battery rack design and specifications

Each battery rack is made up of 8 battery modules in series according to 1P8S configuration. The battery rack is protected by the BCMS and a control box. A DCDC virtual impedance regulator is optional for battery racks used in Aqua-C. The battery rack specification is outlined in Table 4-11.

Table 4-11 Technical specifications of Aqua-C battery rack

Item	Specification	Remark
Rated capacity	280 Ah	25 ± 2°C
Rated voltage	1331.2 V	
Rated energy	372.736 kWh @ 0.5 P	25 ± 2°C
Maximum power	186.386 kW	
Recommended operating temperature	25 ± 5°C	
weight	3000 kg	
Humidity	10 – 85% RH	Non-condensing
Type of installation	Indoor	

Dimensions (Depth x Width x Height)	D: 1130 mm (without modules) W: 930 mm H: 2270 mm

5 SAFETY AND COMPLIANCE EVALUATION

Safety is a critical design and operational aspect of energy storage devices. Safety of an energy storage system builds up from the battery cell and is relevant to every stage of the product's lifecycle, based upon both code requirements and best practices. When assessing an energy storage device's safety program, DNV applies the approach of risk management; that is, the likelihood of an emergency event to occur and the severity of the event. DNV reviews certifications, test data, and quality management processes to address the likelihood factor of the equation; and reviews emergency response, installation protections and suppression/detection systems to address the severity factor of the equation. In general, DNV considers certifications to codes and standards to be minimum requirements. Since codes and standards do not necessarily match up to best practices, DNV expects a robust safety program to go beyond the basic requirements. In this section, DNV has reviewed the BESS safety program.

DNV has reviewed the relevant safety related documentation for the cell, module, and unit used in CLOU's Aero-C and Aqua-C systems. The model numbers associated with this product are found in Table 5-1.

Table 5-1 Model numbers of the BESS components

Component	Aero-C system	Aqua-C system
Cell	REPT: CB71173204EB Hithium: LFP71173207/280Ah	REPT: CB71173204EB Hithium: LFP71173207/280Ah
Module	CL530PB280B20	CL530PB280B52A
Rack	CL532CB280C20**A/B (** = 10 -21, stands for the number of modules)	CL532CB280B5208B
System	CL510C20-900/3010-P24N	CL510C20-P1900/3727-P25N

5.1 Regulatory compliance evaluation

5.1.1 Standards, codes, and testing

The CLOU's BESS and its subcomponents are designed to be compliant with international standards that are generally accepted to demonstrate minimum safety considerations in the system design for US and Canadian installations. These standards include certifications by Underwriters Laboratories (UL), as well as UL and UN testing. A full listing of key standards claimed across several documents is provided in Table 5-2.

Table 5-2. Standards and tests list

Component	Claimed Standard	Description	Certification Status	Issuing Agency
REPT cell	UL 1973:2022	Standard for Batteries for Use in Stationary and Motive Auxiliary Power Applications	Compliant, certificate issued on 29-Dec-2022	TÜV Rheinland
REPT cell	UL 9540A:2019	Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems	Test report issued on 20-Dec-2022	TÜV Rheinland
Hithium cell	UL 1973:2018	Standard for Batteries for Use in Stationary, Vehicle Auxiliary Power and Light Electric Rail (LER) Applications	Compliant, certificate issued on 15-Jul-2022	TÜV Rheinland
Hithium cell	UL 9540A:2019	Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems	Test report issued on 15-Mar-2022	TÜV Rheinland
Aero-C module (REPT cell)	UL 1973:2022	Standard for Batteries for Use in Stationary and Motive Auxiliary Power Applications	Compliant, certificate issued on 05-Aug-2023	CSA
Aero-C module (REPT cell)	UL 9540A:2019	Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems	Test report issued on 27-Jul-2023	CSA
Aero-C module (REPT cell)	UN 38.3	Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, Section 38.3	Compliant, Test report issued on 03-Mar-2022	Guangzhou Customs District Technology Center
Aero-C rack (REPT cell)	UL 1973:2022	Standard for Batteries for Use in Stationary and Motive Auxiliary Power Applications	Compliant, certificate issued on 15-Aug-2023	CSA
Aero-C rack (REPT cell)	UL 9540A:2019	Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems	Test report issued on 08-Aug-2023	CSA
Aero-C system	UL 9540	Energy Storage Systems and Equipment	Expected to complete in 2024 Q3	
Aqua-C module	UL 1973:2022	Standard for Batteries for Use in Stationary and Motive Auxiliary Power Applications	Expected to complete in 2024 Q3	
Aqua-C module (REPT cell)	UL 9540A:2019	Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems	Test report issued on 21-Dec-2023	CSA

Aqua-C module	UN 38.3	Recommendations on the Transport of Dangerous Goods, Manual of Tests and Criteria, Section 38.3	Expected to complete in 2024 Q3	
Aqua-C rack	UL 1973:2022	Standard for Batteries for Use in Stationary and Motive Auxiliary Power Applications	Expected to complete in 2024 Q3	
Aqua-C rack (REPT cell)	UL 9540A:2019	Test Method for Evaluating Thermal Runaway Fire Propagation in Battery Energy Storage Systems	Test report issued on 08-Jan-2024	CSA
Aqua-C system	UL 9540	Energy Storage Systems and Equipment	Expected to complete in 2024 Q3	

5.1.2 UL 9540A testing

UL 9540A testing is a destructive test method used for evaluating the thermal runaway impacts in a BESS and gathering data to assist in assessing or developing mitigation measures for the failure event, propagation of the failure, or consequences of an event, such as an explosion or fire. The test, which does not have pass/fail criteria, can be performed on a cell, module, or unit level. UL 9540A is ANSI accredited and is currently considered to be the most appropriate published methodology to provide comprehensive, consistent, and reliable third-party data for battery failure testing.

DNV has received the testing reports of the cell, module and rack level for CLOU's BESS products based on 4th edition of the standard.

5.1.2.1 Cell level testing

DNV reviewed the UL 9540A test reports for REPT 280 Ah cells and Hithium 280 Ah cells [14] [15]. The external heating method was used to initiate the thermal runaway. Gas venting observed followed by gas and smoke released. The below venting temperature and thermal runaway onset temperatures were averaged among the studied samples.

Table 5-3 REPT 280 Ah and Hithium 280 Ah cells UL 9540A test results

Test parameter	REPT 280 Ah cell	Hithium 280 Ah cell
Thermal Runaway Methodology	External surface heat at 4°C/min to 7°C/min up to thermal runaway	External surface heat at 4°C/min to 7°C/min up to thermal runaway
Gas Venting Temperature	258.4 °C	274.3 °C
Onset of Thermal Runaway Temperature	357.9 °C	330.4 °C
Gas Volume	220 L	Not reported
Gas Composition (volumetric %)	49.35 % H_2, 7.53 % CO, 25.66 % CO_2, 7.14 % C_2H_4, 6.37 % CH_4, etc.	42.47 % H_2, 8.02 % CO, 26.78 % CO_2, 6.38 % C_2H_4, 9.51 % CH_4, etc.
Lower Flammability Limit at ambient temperature	6.1 %	5.6 %
Lower Flammability Limit at gas venting temperature	5.0 %	4.5 %
P_{max}	0.998 MPa	0.864 Mpa

Burn Velocity (S_u)	85 cm/sec	81.3 cm/sec

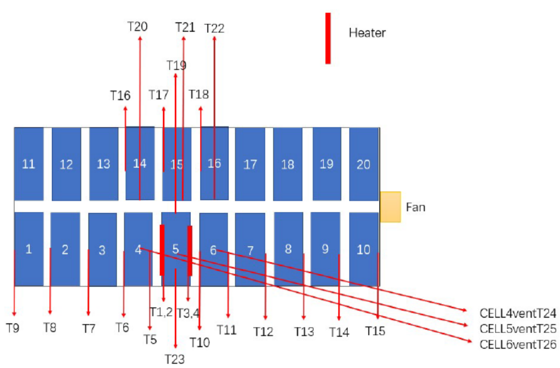
In comparison with other tests DNV has reviewed, the gas composition reported for REPT 280 Ah and Hithium 280 Ah battery cells is consistent with LFP battery cell technology. As such, the battery cells have a high proportion of hydrogen. However, the gas venting temperature and onset of thermal runaway temperature of both cells are much higher the average values DNV has reviewed, which may be due to the temperature measurement positions too close to the heaters.

Although a detailed quantitative analysis of this data would be necessary to determine the exact impact of this, qualitatively, such characteristics could relate to a more energetic explosion. However, the results of the module level and unit level UL 9540A testing will determine the resistance to propagation of thermal runaway events, which would decrease the explosion risk caused by the flammable gas mixture. Other factors to consider are the design of ventilation (such that gases are not permitted to concentrate to levels which could allow an explosion) and volume of the space in which the systems are installed.

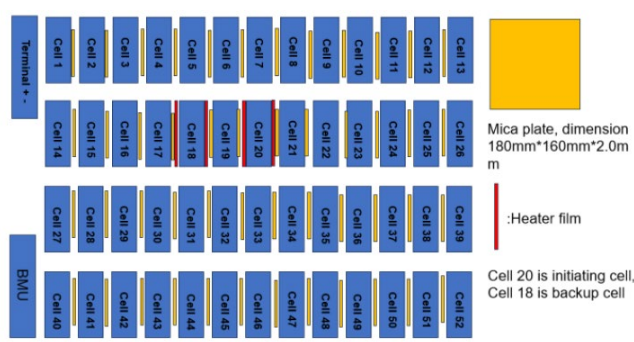
The module-level test results will give insight into propensity for thermal runaway propagation for these cells. If adequate separation or thermal runaway protection is included within the module, the extent of thermal runaway propagation will be minimized regardless of thermal runaway onset temperature. See section below for further details on the module level test.

5.1.2.2 Module level testing

DNV reviewed the UL 9540A test reports for Aero-C module CL530PB280B20 and Aqua-C module CL530PB280B52, both which employed with REPT 280 Ah cells [16] [17]. The reports show that the cell no. 5 of Aero-C module and cell no. 20 of Aqua-C module (film heaters on cell no. 18 were not energized during test) in Figure 5-1 were pasted with two film heaters for each larger surface to initiate thermal runaway.



Aero-C module (REPT cell)



Aero-C module (REPT cell)

Figure 5-1 Cells location for thermal runaway initiating

The initiating cells were heated by film heaters until thermal runaway occurred and propagated to cells nearby. During the tests, a variety of measurements were taken as follows below and the results are summarized in the Table 5-4.

Table 5-4 Aero-C module (REPT cell) and Aqua-C module (REPT cell) UL 9540A test results

Test parameter	Aero-C module (REPT cell)	Aqua-C module (REPT cell)
Thermal runaway initiating method	External heating method with two film heaters	External heating method with two film heaters
Number of cells that were forced into thermal runaway	1	1
Total number of cells that went into thermal runaway	3	3
Measured peak chemical heat release rate (HRR)	11.39 kW	around 4.1 kW
Measured total heat release through the test (THR)	1.6 MJ	around 1.3 MJ
Measured peak smoke release rate (SRR)	0.6466 m^2/s	0.92 m^2/s
Total smoke release (TSR)	166.37 m^2	188.8 m^2
Gas composition	Total 565.8 L: 0 L H_2, 15.8 L CO, 30 L CO_2 and 520 L total hydrocarbons	Total 400.3 L: 0 L H_2, 38.4 L CO, 134.9 L CO_2 and 227.0 L total hydrocarbons
Other observations	No fire or explosion occurred, no flying debris or explosive discharge of gases during the test	No fire or explosion occurred, no flying debris or explosive discharge of gases during the test

There were no flying debris or explosive discharge of gases or external flaming observed during tests. However, CO and hydrocarbons such as methane and propane are explosive and flammable gases. Hydrogen was not detected during the tests that might be due to the test device. Moreover, the gas generated from the battery module contained carbon monoxide should be considered in emergency response plan and emergency response guide due to its toxicity. DNV advises that precautionary mitigation, containment, and treatment being included in emergency response plan and emergency response guide to adequate details.

Since the cell vent gas is flammable, it is essential to perform UL9540A test on battery unit level to determine the fire and explosion behavior and the effect to the adjacent exposures.

CLOU could not provide UL 9540A test reports for Aqua-C modules and Aero-C module with Hithium 280 Ah cells during the review. They are expected to complete in 2024 Q3.

5.1.2.3 Rack level testing

CLOU has performed UL 9540A test on its Aero-C rack (REPT cell) CL532CB280C2021A/B and Aqua-C rack (REPT cell) CL532CB280B5208B [18] [19]. The initiating units (one column in the container) surrounded by two instrumented walls and three target units as Figure 5-2 and Figure 5-3, were arranged for the indoor ground mounted test.

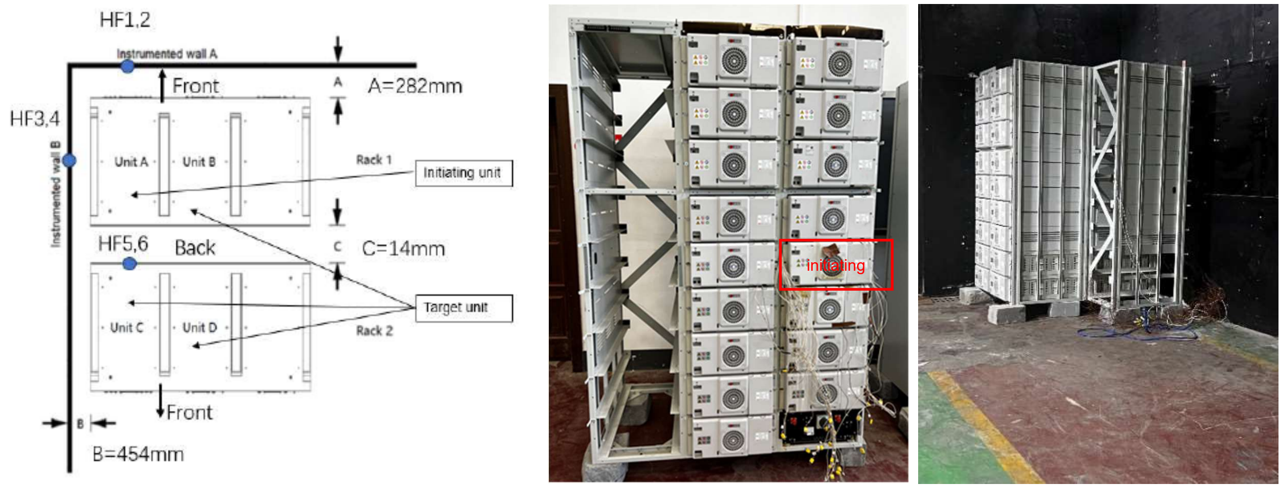


Figure 5-2 Aero-C UL 9540A rack level test layout and set up

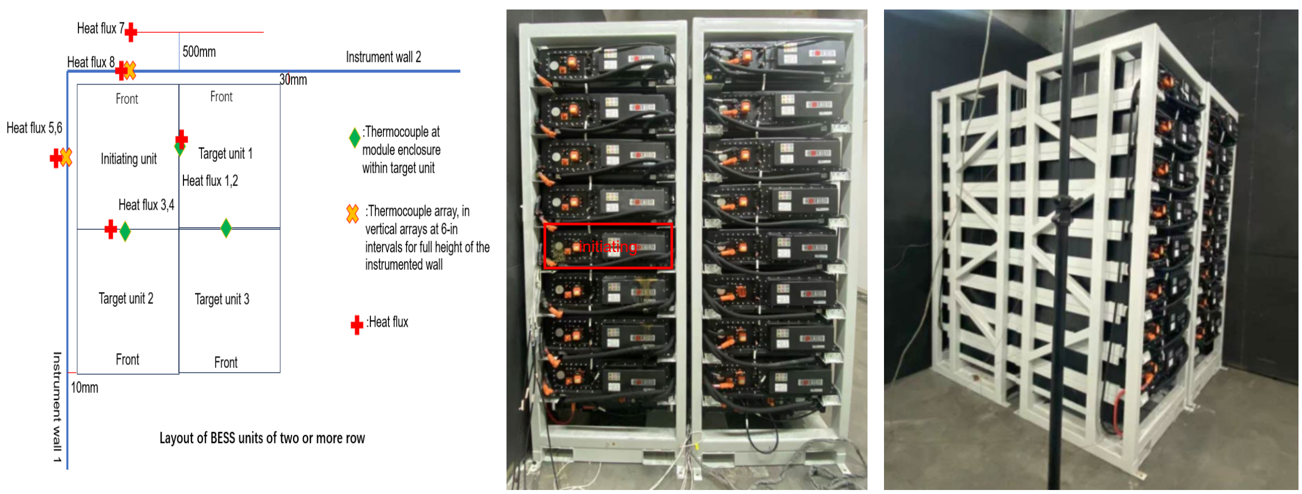


Figure 5-3 Aqua-C UL 9540A rack level test layout and set up

Same heating approaches were applied on the initiating modules as the module level tests. The test reports indicate that no module-to-module thermal runaway propagation occurred, and temperatures and heat flux measured met the unit level performance criteria. Although the rack level tests were treated as UL 9540A unit level test, it is applicable for indoor floor mounted installation. If the battery racks are intended to be installed in a container which has few spaces and high tightness, flammable gas concentrations due to thermal runaway and propagation could be greater than 25% lower flammability limit (LFL), which present high fire and explosion hazards. CLOU shall apply appropriate explosion protection measures to the BESS container which is described in section 5.4.2.

Table 5-5 Summary of rack level UL9540A test results

Test parameter	Aero-C rack (REPT cell)	Aqua-C rack (REPT cell)
Thermal runaway initiating method	External heating method with two film heaters	External heating method with two film heaters

Number of cells that were forced into thermal runaway	1	1
Total number of cells that went into thermal runaway	4	3
Total number of modules that went into thermal runaway (except the initiating module)	None	None
Maximum wall surface temperature	37.3 °C	38 °C
Maximum target BESS temperature	60.4 °C	24 °C
Maximum heat flux	0 kW/m^2	0.13 kW/m^2
Measured peak chemical heat release rate (HRR)	19.88 kW	around 3.2 kW
Measured peak smoke release rate (SRR)	0.2922 m^2/s	0.27 m^2/s
Total smoke release (TSR)	194.24 m^2	114.2 m^2
Gas composition	Total 744.9 L: 0 L H_2, 17.1 L CO, 101.4 L CO_2 and 636.4 L total hydrocarbons	Total 262.86 L: 0 L H_2, 27.62 L CO, 68.72 L CO_2 and 166.52 L total hydrocarbons

5.1.3 UL 9540 certification

UL 9540 is the standard for energy storage systems and equipment, which specifies the requirements to evaluate the compatibility and safety of various components and parts integrated into an ESS.

The UL 9540 certification is ongoing during the review. It is expected to complete in 2024 Q3

5.2 BMS functionality

DNV reviewed the key aspects of the battery management system (BMS). The BMS collects, processes and stores important information during the operation of the battery system in real time, and exchanges information with external equipment to provide real-time alarms and protection during the operation of the battery system.

5.2.1 BMS architecture

As a core component of the battery system, the BMS serves as a bridge between the battery system and external devices, determining the utilization rate of the battery. Its performance is crucial for the cost and safety performance of the BESS. BMS generally adopts a multi-level hierarchical design, and according to the different BESSs, a two-level or three-level architecture scheme is adopted. As Figure 5-4 shows, CLOU's BMS CL5680 adopts a three-layer architecture, mainly composed of a master control unit BAMS (Battery Array Management System) for each DC cabinet, a master control unit BCMS (Battery Cluster Management System) for each battery rack, and a battery acquisition unit BMU (Battery Management Unit) for each battery module [20].

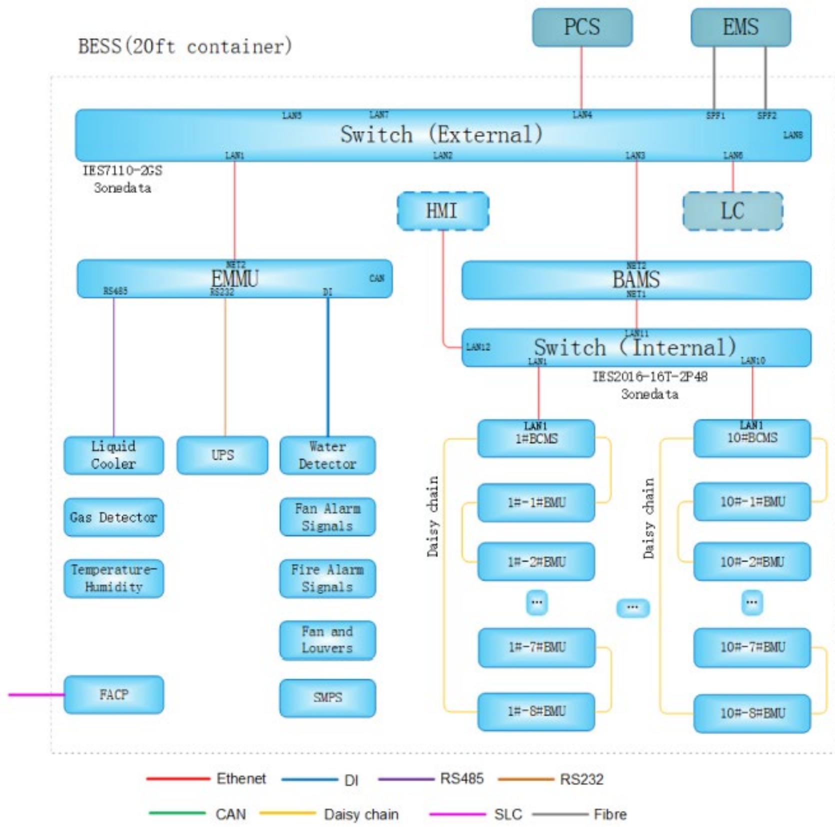


Figure 5-4 CLOU BESS communication and control architecture

BMU is responsible for collecting cell voltage and temperature. BCMS is responsible for collecting cells data, collecting rack current, and conducting charge and discharge management and state estimation of the rack. After obtaining control information from BAMS, the BCMS uniformly manages the access and exit of each rack within the battery system and has functions such as inter racks balancing. In addition, the status parameters of the battery system are also sent to the PCS, so that the charging and discharging power of the PCS is within the acceptable range of the battery. DNV views the BMS architecture and control strategy is in line with the industry practice.

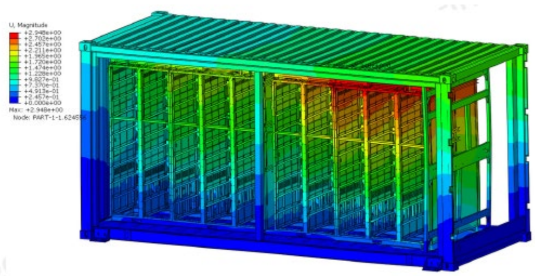
5.2.2 Functional safety

As a critical control system for safety of BESS, BMS shall have high reliability and be verified or evaluated to appropriate functional safety standards, such as Annex H of UL 60730-1, ISO 13849, and IEC 61508, etc. The functional safety report provided by CLOU demonstrates that the BMS complies with Class B to UL 60730-1 and CAN/CSA-E60730-1, which is the minimum requirements of UL 1973 and UL 9540.

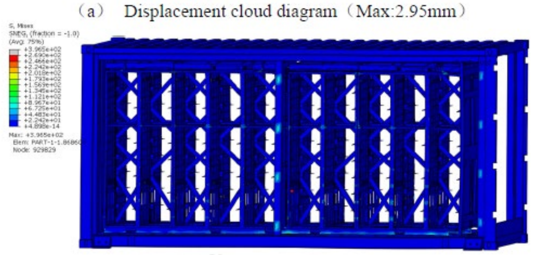
5.3 CLOU enclosure design

The Aero-C BESS is enclosed in a 6,058 mm x 2,438 mm x 2,896 mm 20 feet container rated to IP54 and NEMA 3R. IP code is a coding system to indicate the degrees of protection provided by an enclosure against access to hazardous parts, ingress of solid foreign objects, ingress of water. IP54 indicates the enclosure has a protection degree against dust and splashing water. NEMA type is another rating system for enclosure which is adopted in US standards. NEMA 3R indicates that the enclosure provides a degree of protection of the equipment inside the enclosure against ingress of solid foreign objects (falling dirt) and degree of protection with respect to harmful effects on the equipment due to the ingress of water (rain, sleet, snow). The Aqua-C BESS is enclosed in a same size container rated to IP55 and NEMA Type 3, which provides higher degree of protection than Aero-C BESS. DNV views that both the enclosures are suited for outdoor use.

CLOU's BESSs are intended for installation in seismic environments. CLOU provided simulation analysis reports of seismic response spectrum of Aero-C and Aqua-C container to demonstrate their compliance to certain seismic levels [21] [22]. The simulation for Aero-C was performed according to standard ASCE 7-16, which verified the strength and stiffness of the container in seismic loading, through static analysis, modal analysis and response spectrum analysis. The results of simulation show that Aero-C container can meet the requirements of ASCE7-16. The test report issued by CTTL demonstrates the battery rack complies with the high-performance level requirements of IEEE Std 693-2018 [23] [24].



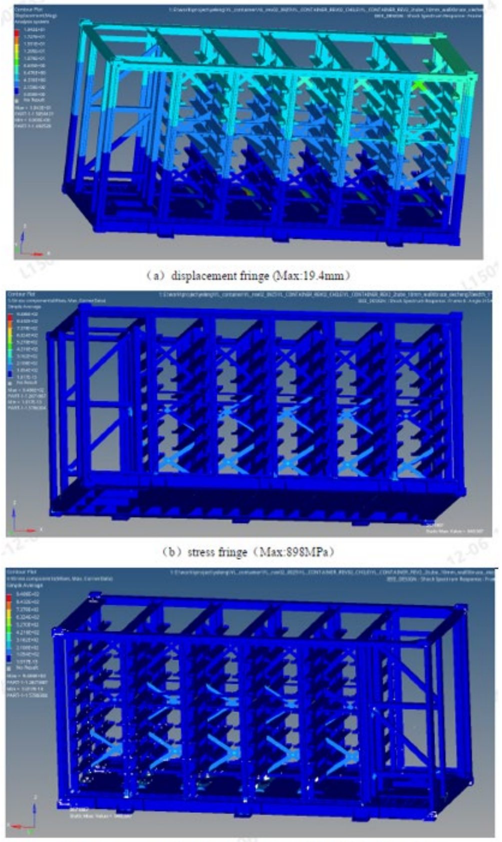
（a） Displacement cloud diagram（Max:2.95mm）



（b） Stress cloud diagram（Max:396.5MPa）

Figure 5-5 Response spectrum analysis of Aero-C container

The simulation analysis for Aqua-C was performed according to standard IEEE 693, which included static analysis, modal analysis and response spectrum analysis. The results of simulation show that only several elements located in weld seam are overstressed because of the stress concentration, the stress of the whole container is less than the allowable of the material, the container structures can meet the requirements of high seismic level in standard IEEE 693.



（c） stress concentration fringe（overstress 269MPa in white color）

Figure 5-6 Response spectrum analysis of Aqua-C container

Due to the seismic environments at different locations present different characteristics and seismic level, DNV recommend CLOU to mark the seismic level on the equipment and the installers shall make sure the BESS will be installed in appropriate locations.

CLOU provided the fire resistance report for the wall of container to standard UL 263. The results show that the wall of container comply with the requirement of 2-hour fire resistance rating, which could reduce the clearances between BESS and exposures.

Furthermore, If BESS is intended for installation outdoors in marine environments, the enclosure shall be corrosion proof and verified in accordance with relevant international standards, such as IEC 60068-2-52. The anti-corrosion tests for Aero-C and Aqua-C are being performed when writing this report.

5.4 Fire and explosion protections

5.4.1 Fire protection system

The fire protection system of CLOU Aero-C BESS contains fire suppression devices, temperature sensors, smoke detectors, gas detectors (H_2 and CO), fire control panel, audible and visual alarm devices as layout of Figure 5-7 [25]. The fire protection system has basic fire detection and alarm functions. Aerosol is employed in the container as suppressant, which is known not to be suitable for thermal runaway based fire. Water is recommended as the preferred agent for suppressing lithium-ion battery fires in some standards, such as NFPA 855. DNV opines that if only aerosol suppression system is employed in BESS, the gas detection system shall continue monitoring the levels of combustible gas, ventilation system shall be effective to prevent the concentration of flammable gas. CLOU shall develop elaborate fire protection strategy. DNV recommends the BESS reserve extinguishing water connection in the container as the last line of defense in case of fire.

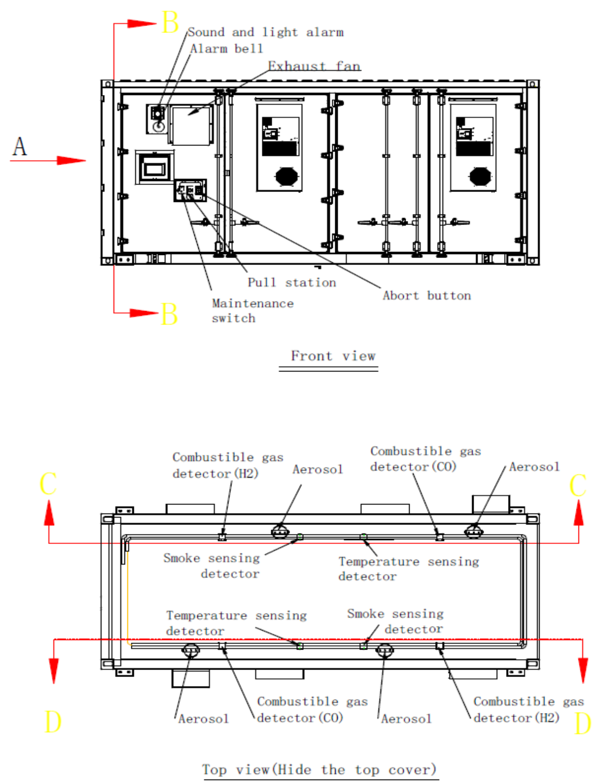


Figure 5-7 Aero-C FSS layout

CLOU Aqua-C BESS contains both aerosol fire suppression system and water sprinkler system, which is a favorable practice.

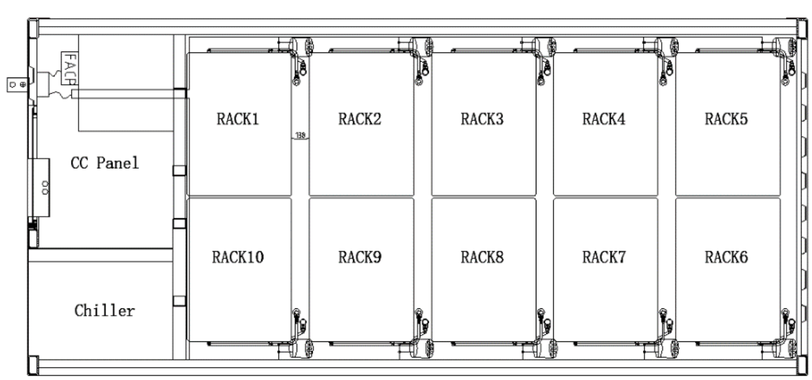


Figure 5-8 Aqua-C aerosol fire suppression system layout

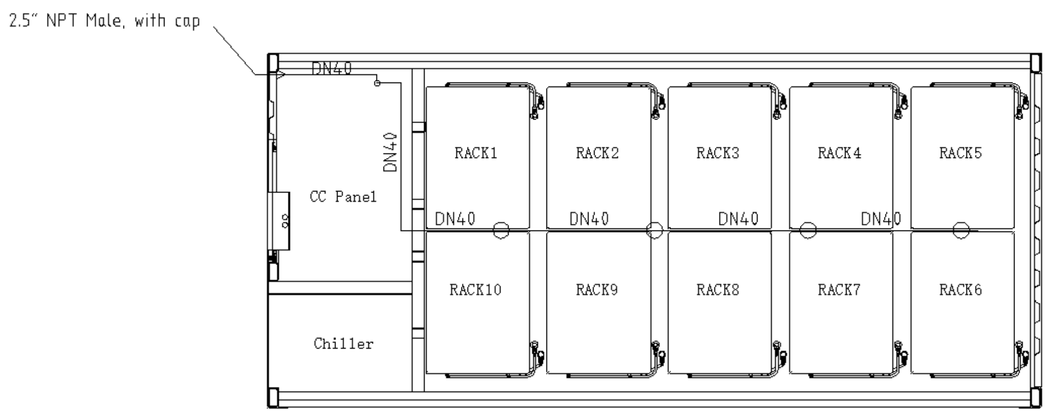


Figure 5-9 Aqua-C water sprinkler system layout

5.4.2 Explosion protection measures

CLOU installs active ventilation system in the container for both Aero-C and Aqua-C to reduce the concentration of flammable gas below 25% of the Lower Flammability Limit (LFL) as an explosion prevention measure according to NFPA 69. H_2 sensors and CO sensors are equipped to detect the concentration of flammable gas. CLOU designed the ventilation system with ventilation rate of 0.27 CFM/kWh, which referred to DNV's report [26]. However, the effectiveness of ventilation system as an explosion protection measure may be affected by many aspects, such as the characteristics of cells, modules and racks, the air flow streams for containers, the sensitivity of gas defection devices, and the response timing of the whole system. CFD simulation is a best practice to verify that the ventilation system is adequately sized and in line with NFPA 69.

The CFD simulations for Aqua-C ventilation system are based on several assumptions: different number of cells in thermal runaway, different flow rates, etc. The results show that [27]:

- when the ventilation rate is at 100% (820 CFM), the maximum flammable gas concentration does not exceed 25% LFL for any scenario – 3-cell, 26-cell and 52-cell leak.
- When the ventilation rate is at 50% (410 CFM), the maximum flammable gas concentration does exceed 25% LFL for the 26 and 52 cell leak scenarios. However, it does not exceed 25% LFL for the 3-cell leak scenario that is attested during the UL9540A testing.
- When the ventilation rate is 700 CFM, the maximum flammable gas concentration does not exceed 25% LFL.

The UL9540A module level and unit tests show that total 3 cells went into thermal runaway. Hence, current ventilation system is able to maintain the flammable gas concentration below 25% LFL and has a wide safety margin even considering the blockage of air flow.

Although Aero-C has similar ventilation system, its effectiveness could not be equivalent to above simulation results due to the differences of construction, air flow and number of cells.

5.5 Electrical safety

Electrical hazards could present in BESS during operation and maintenance as electric shock, overcurrent, arc flash, and so on, which shall be protected with appropriate measures.

Electric shock is a kind of common electrical hazards and has been considered in the standards, codes and regulations for the electric components and equipment. Compliance with these standards, codes and regulations could meet the minimum requirements against electric shock.

Due to the high short-circuit current of batteries, overcurrent protection is essential in the BESS. The single-line drawing of CLOU's Aero-C BESS shows that both fuse and circuit breaker are equipped at each battery rack and each DC cabinet (4 racks in parallel). The ratings and breaking capacity could be compatible with the batteries. Aqua-C BESS has similar circuit design. DNV views that it is in line with the industry practice.

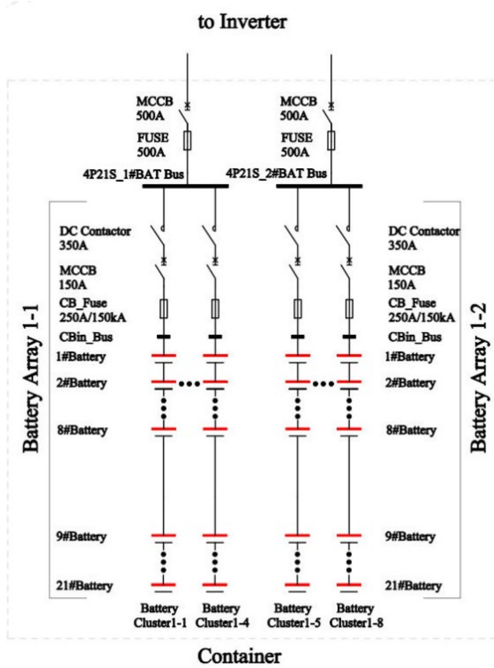


Figure 5-10 Single-line drawing of Aero-C BESS

Arc flash is a kind of electrical explosion or discharge, which occurs between electrified conductors during a fault or short-circuit condition. There is no possibility to completely avoid arc flash hazards when working near live parts, such as the terminals of batteries. The incident energy of arc flash and personal protection equipment (PPE) ratings shall be evaluated and marked on the equipment. CLOU assessed the DC arc flash risk for Aero-C and Aqua-C BESS to NFPA 70E and IEEE 1584 and provided appropriate warning labels [28]. DNV views it is in line with the best practice of the industry.

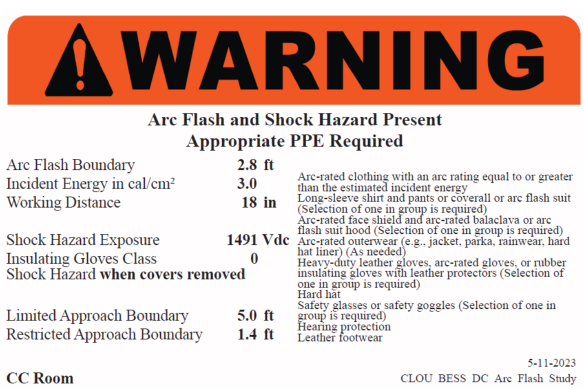


Figure 5-11 Aero-C CC room arc flash label

5.6 Hazard mitigation analysis

The hazard mitigation analysis (HMA) is an industry best practice that is established by NFPA 855. NFPA 855 is the Standard for the Installation of Stationary Energy Storage Systems, which DNV views as the most comprehensive set of best practice guide in the industry.

DNV reviewed the HMA (product level) provided by CLOU for its BESS. The document lists several common risk events, related sources, and protection strategies.

DNV recommends a CLOU BESS specific HMA being developed in accordance with the requirements of NFPA 855.

5.7 Emergency response guide

Emergency Response Guide (ERG) serves as a resource for emergency responders to address foreseeable hazards associated with the on-site systems. DNV reviewed CLOU Containerized Battery Energy Storage System (BESS) Emergency Response Plan, which introduces system safety design and emergency measures for different scenarios, such as electrolyte leakage, coolant leakage, emergency shut down or stop, and fire protection. DNV finds the emergency response guide is in line with industry practice.

ERG is a generic guide for emergency response that will require site-specific updates on a project-by-project basis. As such, DNV recommends that the emergency operations plan for a specific facility shall be updated to include all relevant site-specific information for each project. Typically, the emergency operations plan should be effective from the start of commissioning and the end of decommissioning periods.

6 INSTALLATION AND INTEGRATED SYSTEM EVALUATION

6.1 User Manual

CLOU's BESS user manual for Aero-C provides below guides for users:

- the product design and specification
- transportation requirements
- installation requirements and procedure
- power on and power off
- human machine interface (HMI)
- troubleshooting
- SOC calibration instructions
- routine maintenance
- fire protection instructions

In general, DNV finds the manual to be aligned with industry standard practices.

Installation environment requirements contain the requirements for site selection, foundation and installation space. Spacing requirements between BESSs are showed in Figure 6-1. In general, there is a certain clearance distance between BESS units to prevent a firer originating in a single unit spreading to adjacent units. The enclosure of CLOU's BESS has 2-hour fire resistance rating in accordance with UL 263 [29], which could prevent the fire from occurring in the container to adjacent container. The separation distance is permitted to be reduced to 0.9 m according to NFPA 855. The minimum distance 1500 mm between BESS or BESS groups could meet this requirement.

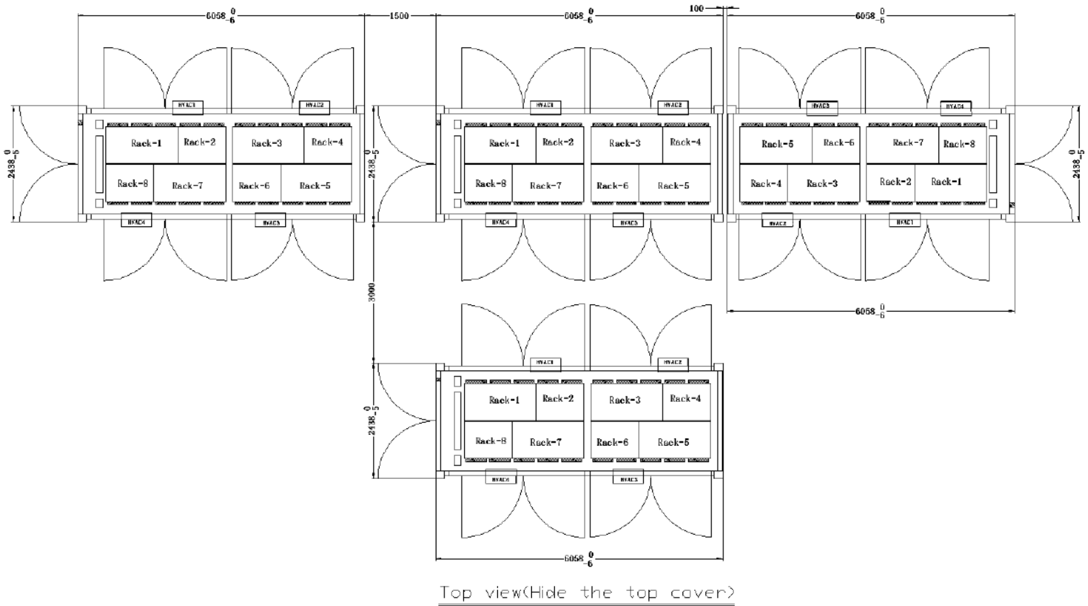


Figure 6-1 Aero-C BESS installation spacing

DNV reviewed CLOU's BESS user manual for Aqua-C, which has similar content and issue.

6.2 Commissioning

CLOU provided a typical on-site work schedule for site acceptance test (SAT), which contains below stages:

- acceptance check
- installation & pre-heating
- cold check
- running check
- system balancing
- capacity test

Total period is about 3 months, and many tests will be performed on site. DNV views the SAT is in line with industry standard.

6.3 Maintenance

DNV reviewed CLOU's BESS maintenance manual, which describes follow:

- maintenance management standards
- maintenance team
- safety

- maintenance preparations
- routine maintenance
- BESS maintenance checklist
- BESS after sale and response
- Troubleshooting
- Battery / BMS / Control box / maintenance
- Fire suppression system guidance
- BESS environment guidance

Detailed safe operation guide is specified in the BESS Energy Control Plan. In general, DNV finds the manual and the control plan to be aligned with industry standard practices.

7 QUALITY AND MANUFACTURING REVIEW

As described in Section 2, currently CLOU's BESSs are produced at its manufacturing facility located in Yichun, China. This section describes DNV's evaluation of the factory Yichun CLOU Energy Storage Technology Co., Ltd. (hereafter Yichun CLOU), which is a wholly owned subsidiary of Shenzhen CLOU Electronics Co., Ltd. The company was established in November 2017, with the first phase of an area of over 73,000 m^2. The second phase is under construction which covers an area of around 67,000 m^2. Yichun CLOU produces battery modules and BESSs. The production capacity is determined by battery modules production as Table 7-1.

Table 7-1 Yichun CLOU module production capacity

No.	Production line	Quantity	Annual Capacity (MWh)	Remark
1	Manual MODULE Assembly Line	1	300	Operational
2	Semi-Automatic Air-Cooling MODULE Production Line for 280 Ah Cells	2	2,000	Operational
3	Automated Air-Cooling MODULE Production Line for 280 Ah Cells	1	1,200	Operational
4	Automated Liquid-Cooling MODULE Production Line for 280 Ah Cells	1	1,600	Operational since November 2023
Total		5	5,100	

7.1 Quality System Overview

Yichun CLOU Energy Storage Technology Co., Ltd. is certified to ISO 9001 Quality Management Systems, ISO 14001 Environmental Management Systems and ISO 45001 Occupational Health and Safety Management Systems.

Figure 7-1 Yichun CLOU ISO 9001 & ISO 14001 & ISO 45001 certificates

Yichun CLOU has several functional departments as Figure 7-2. Production department is divided into four teams based on different processes, which include cable processing team, module (identical to "module" described in above) team, wiring team and structure team. Quality team, testing team and laboratory are responsible for daily quality management activities.

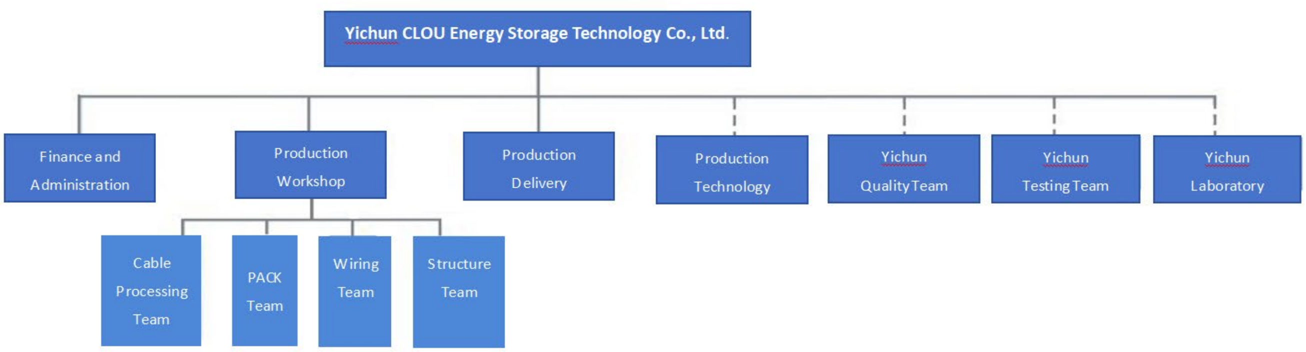


Figure 7-2 Organization chart of Yichun CLOU

Quality management concept of Yichun CLOU is showed in Figure 7-3, which includes several aspects related to the quality, such as people, machine, material, mothed, environment, measurement, and management. These aspects are implemented in different activities, for example, the training for people, first in first out (FIFO) for material management, etc.

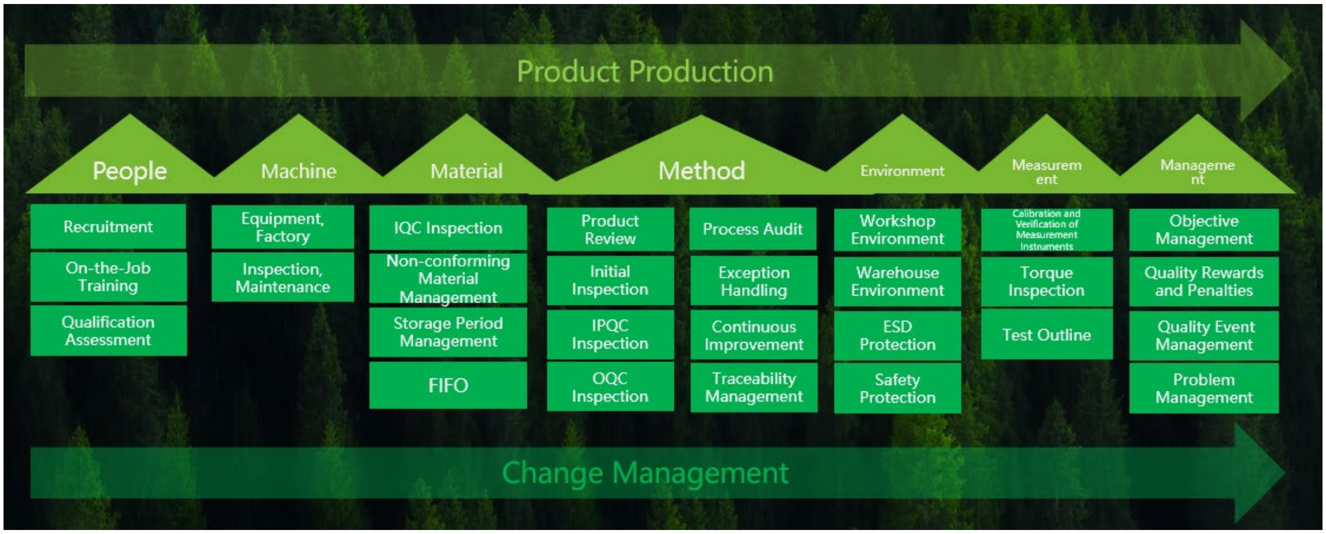


Figure 7-3 Quality management concept

DNV reviewed the latest internal audit report and records. The internal audit for Yichun CLOU was conducted on October 17 and October 18, 2023, according to the requirements of ISO 9001, ISO 14001, and ISO 45001. The report indicates that the internal audit was arranged properly, and the non-conforming findings were corrected with clear causes analysis and corrective actions. DNV views that the overall quality management system is in line with industry standard.

7.2 Supply chain management

DNV reviewed CLOU's Supplier Development and Qualification Working Instruction and supplier audit record. CLOU has some basic requirements and a preliminary audit process for new suppliers. The suppliers are divided into four categories based on the importance and the value of the materials or components provided by the suppliers. For example, if a supplier provides components with high importance and high value, it is categorized as the first priority supplier. Based on the categories, CLOU has different audit requirements.

For the approved and qualified suppliers, CLOU conducts periodic performance evaluation and annual audit on these suppliers to ensure consistency of the quality and performance of their approved lists. DNV views the supplier management is in line with the industry standard.

Additionally, DNV was informed that the supply chain management would be merged with the procedures of Midea group.

7.3 CLOU manufacturing facility visit

Yichun CLOU Energy Storage Technology Co., Ltd. is located at No. 358, Chunhua Road, Yichun Economic and Technological Development Zone, Yichun City, Jiangxi Province, P. R. China. Figure 7-4 shows the entrance to the company.

Figure 7-4 Yichun CLOU Energy Storage Technology Co., Ltd.

The factory visit was conducted on 5th December 2023 by DNV, and was focused on two elements:

- the overall quality control review
- BESS production process characterization and production process quality control

DNV visited Yichun CLOU's incoming inspection area and warehouse. The incoming inspection area was divided into several small areas to manage the materials or components at different stages, such "to be inspected", "inspected OK" or "inspected NG (Not Good)". Each area was marked with clear label and frame, and non-conforming materials were fenced in designated, red-framed area. DNV opines this approach for non-conforming materials management is favorable.

Figure 7-5 Incoming inspection area and non-conforming materials area

DNV visited Yichun CLOU's warehouse, which stored raw materials and components. The warehouse was well organized and managed via SAP system. Battery cells were stored in a separated room with air-conditioning to control the environment within the specification.

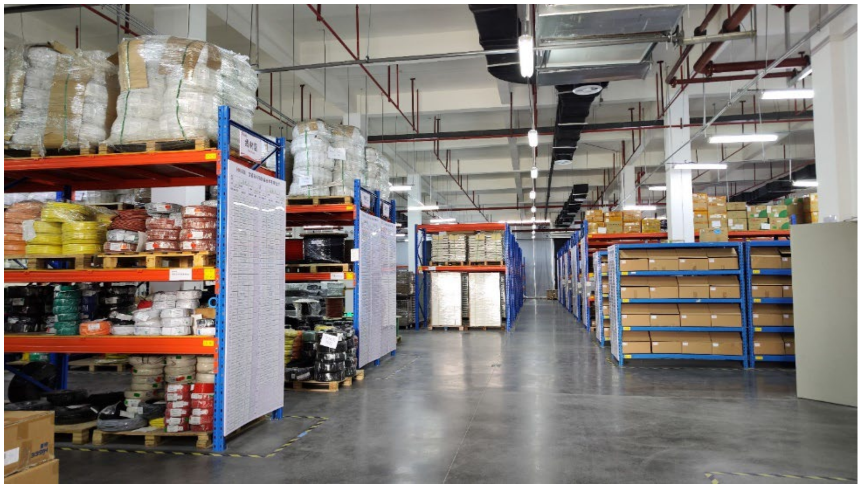


Figure 7-6 Warehouse

There are four processes for BESS manufacturing at Yichun CLOU factory as Figure 7-7, including module production, BMS assembly, wiring harness and BESS assembly. Figure 7-8 shows the overview of each workshop. BMS assembly is arranged in wiring harness workshop, and BESS assembly is divied into two workshops, control cabinet assembly workshop and BESS container assembly. OrBit Manufacturing Execution System (MES) is used for manufacturing management.

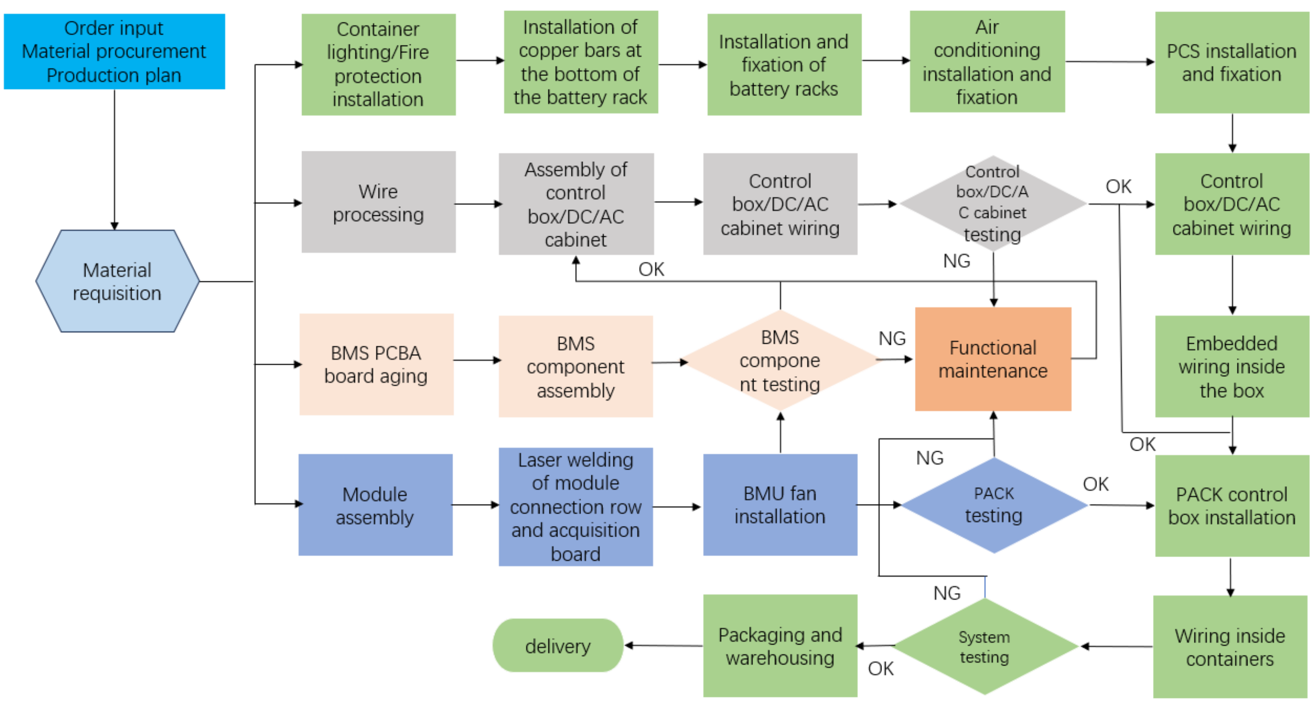
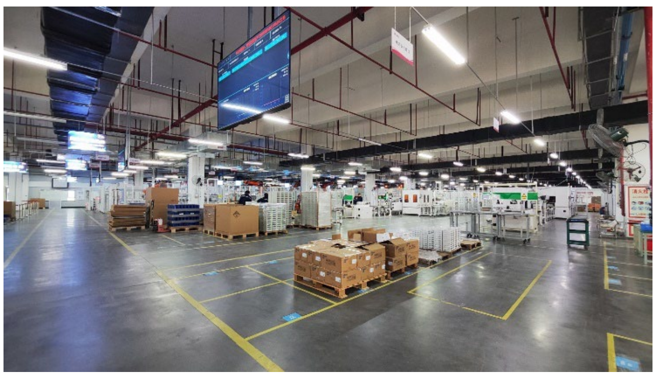


Figure 7-7 Process flow chart

Wiring harness

Control cabinet assembly



Battery module production lines

BESS container assembly

Figure 7-8 Workshops

The production lines were organized systemically. Working instructions were displayed on the LCD panel at each working station. Materials and components were placed in the designated areas. DNV witnessed the terminal crimping and checked the measurement record for pull test, which indicates that the quality was controlled within the specification.

DNV visited the battery module workshop and found that there was no access control and environment control between battery module workshop and other workshops. The doors were opened to the outside, where every worker could access. Generally, battery module shall be produced in a high cleanness environment. DNV opines that necessary measures shall be taken to improve the access control and environment control.

There were five production lines in battery module workshop, including one manual line, two semi-automatic air-cooling module lines, one automatic air-cooling module line and one automatic liquid-cooling module line, which reflected the upgrading process of the manufacturing. During the visit, the automatic air-cooling module line and liquid-cooling module line were in trial, and the machines were calibrated accordingly. DNV witnessed the safety test at semi-auto air-cooling module line and found that the worker operated correctly.

When the BESS container was assembled completely, it was transported to the system testing area as Figure 7-9. Then the BESS will be tested according to the factory acceptance test (FAT) protocol for each project. DNV reviewed the FAT report and found that the visual inspection, key functions check, safety tests and capacity test was performed with positive results. DNV recommends to relocate the testing area to indoor environment or take other measures to avoid the effect of weather.

Figure 7-9 System testing area

8 PRODUCT SUPPORT

DNV reviewed CLOU's after sale service solution and commitment documentation.

8.1 Service organization overview

CLOU has established local after-sales service offices in relevant countries and regions as showed in Table 8-1. These offices include local after-sales technical team and spare parts warehouse. More than 90 % of the field application engineers (FAE) has gotten high-voltage circuits operation certificates. CLOU informed DNV that they have accumulated 1 GWh industry experience.

Table 8-1 CLOU after-sales service offices

Nation	Region	Warehouse	Recent after-sales service staff
China	Shenzhen	Block A, Clou Building, No. 99 Baoshen Road, Nanshan District, Shenzhen, Guangdong Province	15
	Yichun	No. 358, Chunhua Road, Yuanzhou District, Yichun City, Jiangxi Province	13
USA	Texas	8603 Red Bluff Rd Pasadena Texas, 77507, United States	5
	California	401 Kato Terrace Fremont, California, 94539, United States	5
	Indiana	2801 N.575 W Bargersville, Indiana, 46106, United States	3

Chile	Atacama	Km 25 al Noreste de la ciudad de Copiapó, Sector Llanos de Chulo, Comuna de Copiapó, Provincia de Copiapó, Atacama, Chile	3
	Atacama	Camino Minero S/N°, Sector Llano Indio De La Plata, Diego De Almagro, Chanaral, Atacama, Chile	
Greece	Athens	Long-term planning and construction	2

CLOU also has many partners listed in Table 8-2 to provide installation, commissioning, and maintenance services.

Table 8-2 CLOU's partners

Company	Industry	Location	Business Scope
CLEAN ENERGY SERVICE	Wind, solar, and energy storage	Houston, Texas, USA	Installation and commissioning, annual maintenance, site management and QC, Supplementation
SABER POWER	Industrial / commercial electric	Houston, Texas, USA	Accessory installation, Pre-commissioning, Circuit breaker maintenance program, Retrofitting, Upgrades / calibrations
INGENOVA	Energy	Santiago, Chile	Turnkey engineering, supply and construction, infrastructure generator supplies, Supply, Assembly and Commissioning
OTEKCATL SERVICE CENTER	Battery energy storage	Houston, Texas, USA	Start-Up & Commissioning, Maintenance & Recall, Battery Management Software Optimization, Battery Recycling & Reuse

DNV views CLOU has established certain global support network. However, the service quality and response time vary based on the location, scale, and the quality of specific project.

8.2 Warranty

CLOU Warranty Agreement & CLOU Long Term Service Agreement (LTSA) combines the terms of warranty agreement and long term service agreement. It consists of following articles [30]:

- Maintenance services
- Replacement of parts
- Payment
- Guarantee
- Intellectual property
- Confidentiality
- Indemnification

- Term and termination
- Governing law and dispute resolution
- Force majeure
- Miscellaneous

These articles provide a standard warranty and LTSA framework which varies with different customers and projects.

The standard warranty offers three warranty plans shown in Table 8-3, which covers operation and maintenance (O&M), technical support, annual inspection, performance and availability guarantee, spare parts, etc. DNV opines the terms are in line with the industry standard. However, DNV has not received and reviewed the detail information on performance guarantee and availability guarantee under Technical Agreement.

Table 8-3 CLOU standard warranty plans

Feature	Warranty Plan 1	Warranty Plan 2	Warranty Plan 3
Warranty Period	3 years	3 years	3 years
Service Levels Covered	L1 L2 L3 Included	L1 L2 L3 Included	L2, L3 included
O&M	Included	None	None
Remote Technical Support	Included	Included	Included
Annual Inspections	Once every year	Once every year	Available for a fee
Performance Guarantee	Included	Included	Included
Availability Guarantee	Included	Included	Available for a fee
Spare Parts	Included	Included	Included
PCS SKID	Local + Remote	Local + Remote	Remote + Local On Call
EMS	Remote24/7	Remote24/7	Remote24/7

The standard free warranty period 3-year is the minimum requirement in the industry. CLOU also offers extended product warranty, where applicable, it could be purchased along with the purchase of the products. The longest product warranty period that CLOU may offer is 20 years but may be limited based on the type of product purchased by the buyer and the intended use case, and the buyer can purchase the services according to their own needs. Based on current industry standard, there is no reliable evidence which could demonstrate 20 years life of BESS. DNV recommends that detailed warranty terms and LTSA shall be reviewed and evaluated judiciously for specific project.

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APPENDIX A – AERO-C (CL510C20-900/3010-P24N) TECHNICAL SPECIFICATIONS

NO.	Items	Parameters	Remark
1	Nameplate energy	3010kWh	
2	Max. charge/discharge power	903kW	
3	Nominal DC voltage	1344V	
4	DC Voltage (Full power)	1113-1480V	
5	Auxiliary power supply	480Vac, 60Hz	Optional: 400Vac 50Hz
6	SOC calculation accuracy	±3%	
7	SOH (End of Life)	60%	
8	Environmental temperature	-20℃ ~ 45℃	
9	Environmental humidity	≤95%RH	Non condensation
10	Altitude	< 2000m	
11	Noise	< 75dB(A)	@1m
12	Protection grade	NEMA 3R / IP54	
13	Corrosion-proof grade	C4 (EN ISO 12944)	
14	Snow/ice loads	10 lb/sqft	
15	Wind loads	115mph	
16	Seismic level	Risk Category: III Site Class: D SS: 0.232 S1: 0.111 SMS: 0.371 SM1: 0.265 SDS: 0.247 SD1: 0.176	
17	External communication interface	Ethernet	Copper and fiber
18	Dimensions (W*D*H)	6058*2438*2896mm	3*20ft HC container
19	Design life	20 years	

APPENDIX B – AQUA-C (CL510C20-P1900/3727-P25N) TECHNICAL SPECIFICATIONS

NO.	Items	Parameters	Remark
1	Nameplate energy	3727kWh	
2	Max. charge/discharge power	1863kW	
3	Nominal DC voltage	1331.2V	
4	DC Voltage (Full power)	1165-1500V	
5	Auxiliary power supply	480Vac, 60Hz 400Vac, 50Hz	
6	SOC calculation accuracy	±3%	After calibration
7	SOH (End of Life)	60%	
8	Environmental temperature	-30℃ ~ 50℃	
9	Environmental humidity	≤95%RH	Non condensation
10	Altitude	< 2000m	
11	Noise	< 75dB(A)	@1m
12	Protection grade	NEMA Type 3R / IP55	
13	Corrosion-proof grade	C4 (EN ISO 12944)	
14	Snow/ice loads	80 lb/sqft	
15	Wind loads	147mph	
16	Seismic level	meet the requirement of IEEE693 STANDARD HIGH CLASS DESIGN LEVEL seismic	
17	External communication interface	Ethernet	Copper and fiber
18	Dimensions (W*D*H)	6058*2438*2896mm	
19	Design life	20 years	

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