WORKSHOP ON HYBRID ENERGY STORAGE SYSTEMS ORIENTED TO MARITIME APPLICATIONS

Battery concepts from the mechanical point of view

Eva-Maria Stelter
10.06.2022 /Hernani /Spain

Content

1. Basics of Lithium-Ion battery systems
2. Architecture
3. General Requirements for marine application
4. Overview mechanical design and validation process

SEA BAT

Fraunhofer LBF

Basics

Lithium-Ion applications:

- BEV, HEV
- E-Bike
- Notebook
- Smartphone
- Power Tools
- Ferries, Harbour Tugs

Advantages:

- High energy density
- High charge/ discharge cycle stability
- Low self-discharge rate

Picture source: pixabay.de

Basics

Lithium-Ion applications:

- BEV, HEV
- E-Bike
- Notebook
- Smartphone
- Power Tools
- Ferries, Harbour Tugs

Challenges:

- Temperature sensitivity
  - Operational use: -20°C - 60°C
  - Best performance: 18°C - 25°C
- Fire characteristic

Picture source: pixabay.de

Basics

Thermal runaway causes

1

Cell external
- Short circuit
(fuse failure, short circuit between cells)
- External fire

- Cell internal safety device
- Electrical isolation
- Thermal isolation, cooling

2

Cell internal
- Over charge (Lithium dendrites)
- Deep discharge (Copper dendrites)
- Internal short circuit (e.g. due to crush)
- Bad quality

- Battery management (charge and discharge control)
- Mechanical design
- Quality control during production

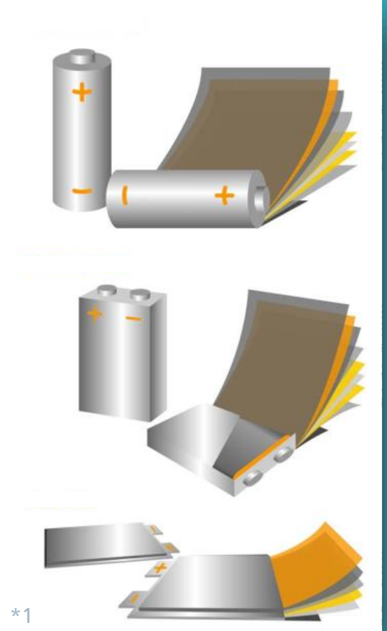
source: Batterieforum Deutschland, S. Scharner, „QUANTITATIVE CHARAKTERISIERUNG DES SICHERHEITSVERHALTENS VON LITHIUM-IONEN ZELLEN", Berlin, 25. Januar 2018.

Basics

Cell format

Lithium-ion cells are used in three different formats

- Cylindrical
- Prismatic
- Pouch/ Coffee bags



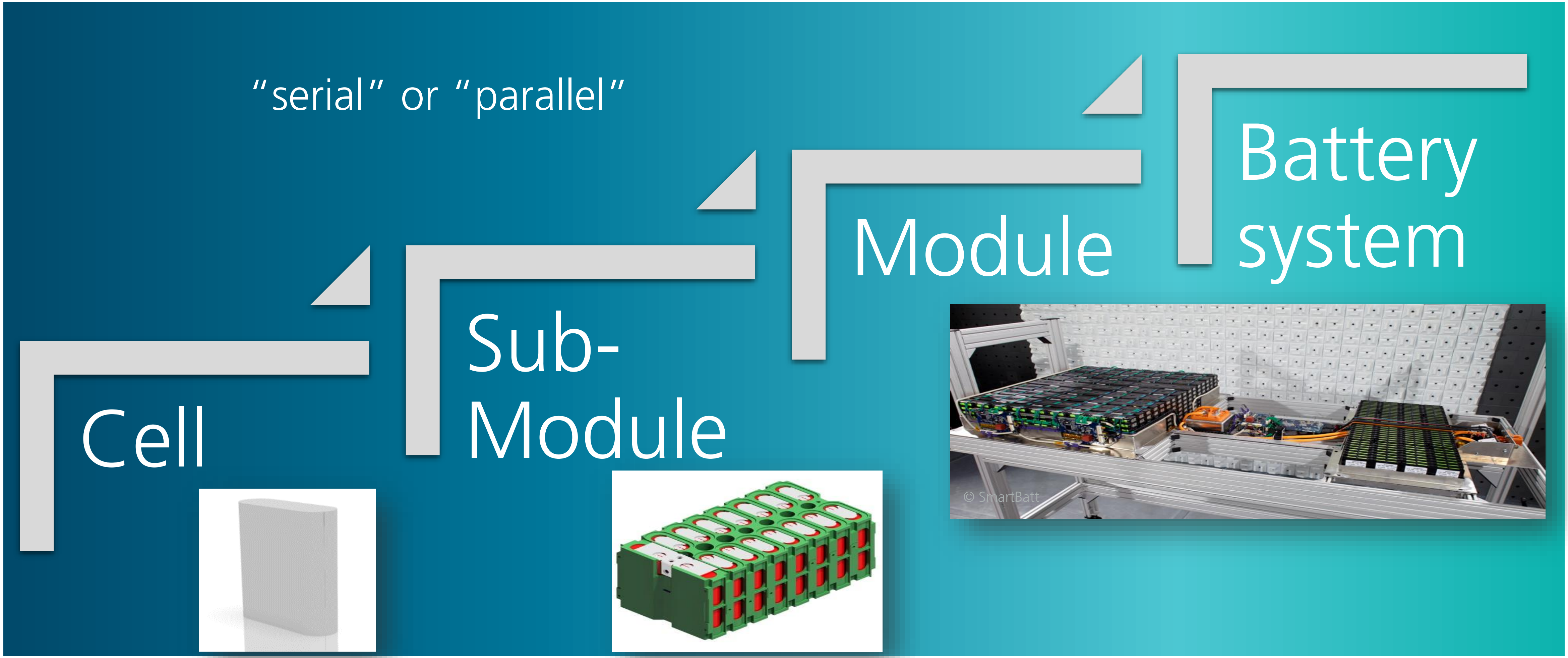
*1

*2

*1 Source: VDE, Kompendium Li-Ionen-Batterien, Grundlagen, Bewertungskriterien, Gesetze und Normen, 2015.
*2 Source: tradekorea.com

Basics

Cell to Battery System



Basics

Cell to Battery System

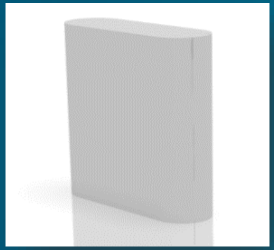
Energy = 24 kWh
Number of cells= 2688
Cell weight= 121 kg
Number of modules= 16

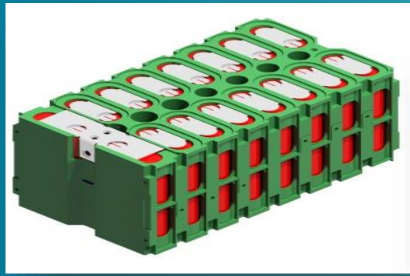
Battery system

Module

Sub-Module

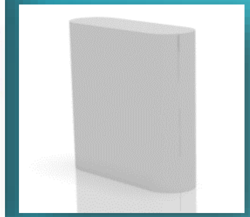
Cell





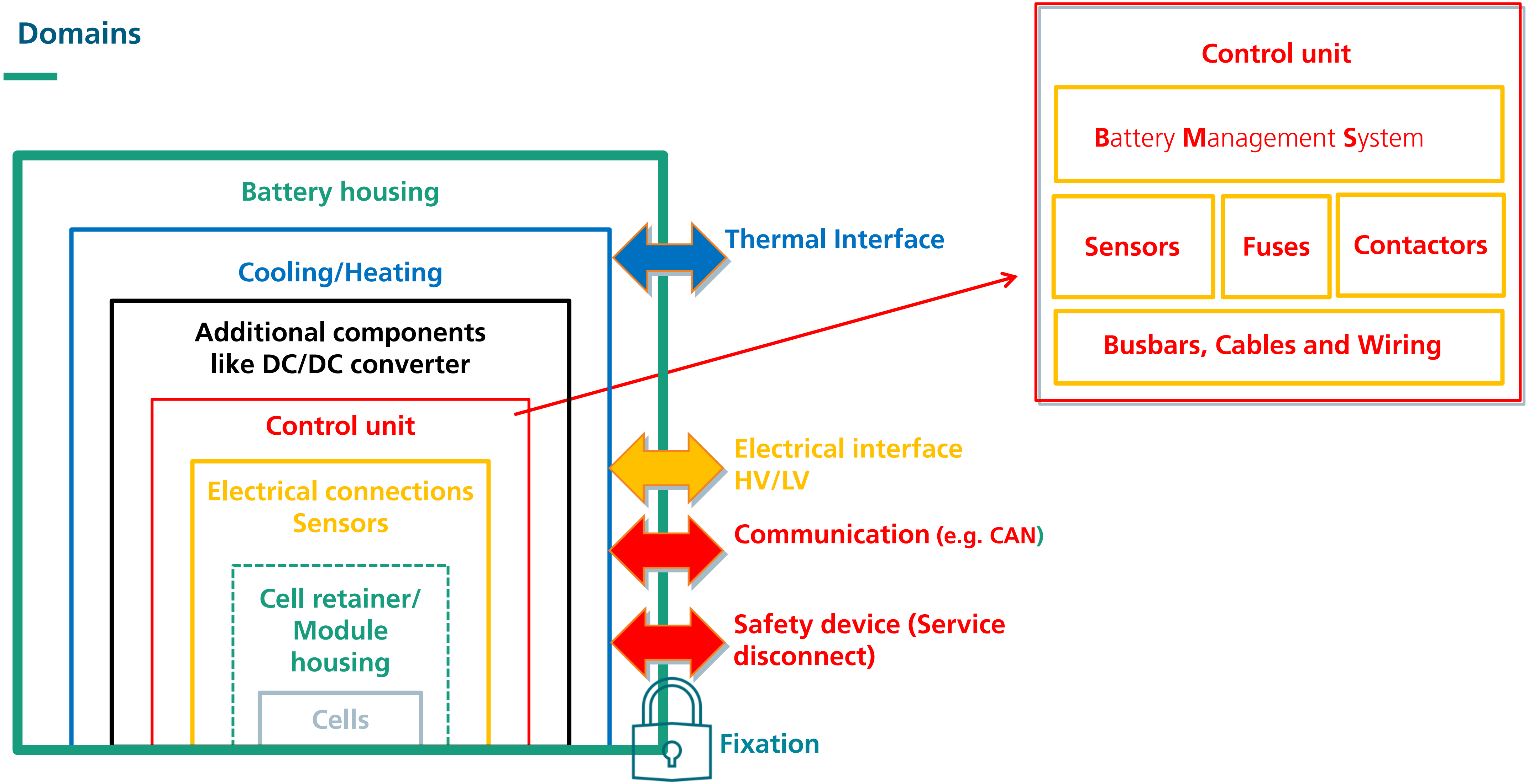
Energy = 23 kWh
Number of cells= 1376
Cell weight= 125 kg
Number of modules= 86

© SmartBatt



Architecture

Domains

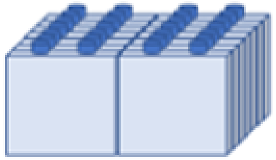
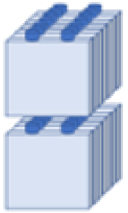


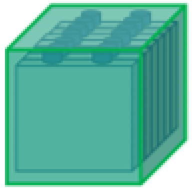
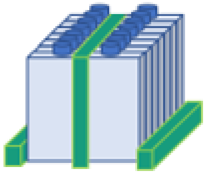
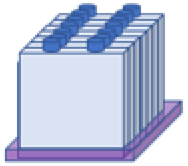
Architecture

Components

Electrical connections
Sensors

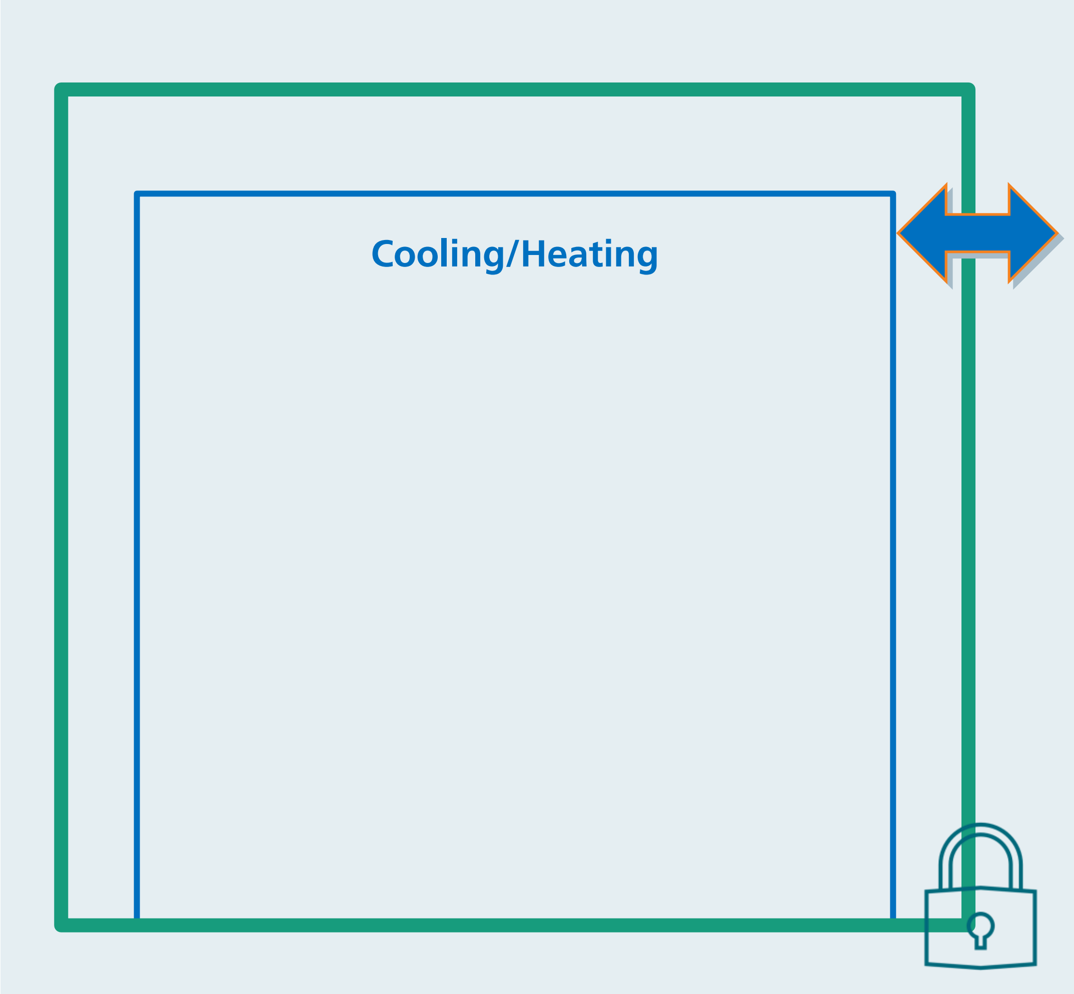
Cell retainer/
Module
housing

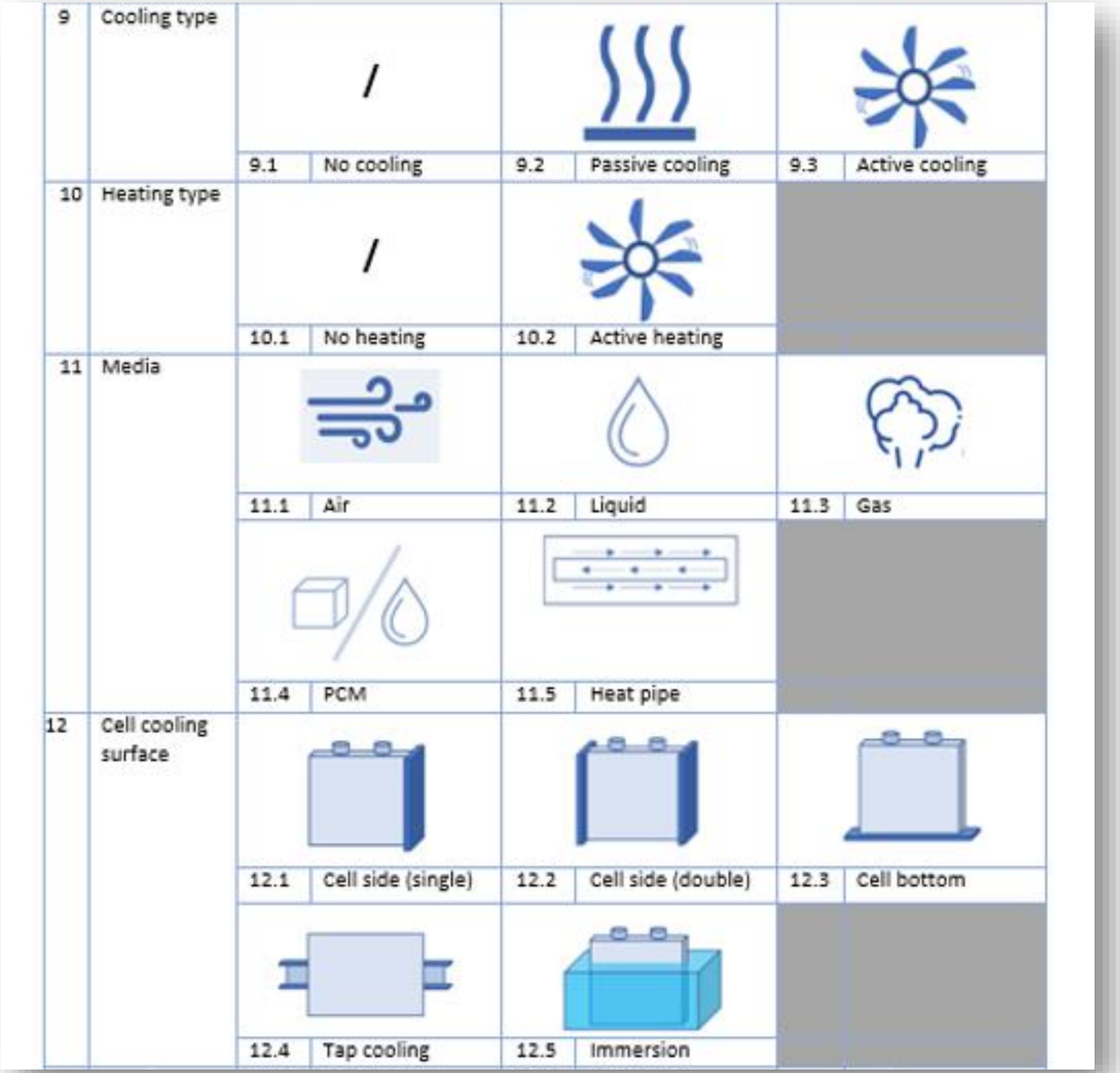
#C	Key feature	#	Solution	#	Solution	#	Solution
4	Cell orientation						
		4.1	**Upright**	4.2	Upside down	4.3	Flat
5	Package - Line up					....	
		5.1	One row	5.2	Two rows	**5.3**	**....**
6	Package - Stack level					....	
		6.1	**One layer**	6.2	Two layers	6.3	....

#C	Key feature Mechanical	#	Solution	#	Solution	#	Solution
7	Cell fixation type						
		7.1	**Capsuled**	**7.2**	**Retainer**	7.3	Glued
8	Cell fixation material	**8.1**	**Metal**	**8.2**	**Plastic**	**8.3**	**Composite**
		8.4	**Rubber**	8.5	Adhesive		

Architecture

Components





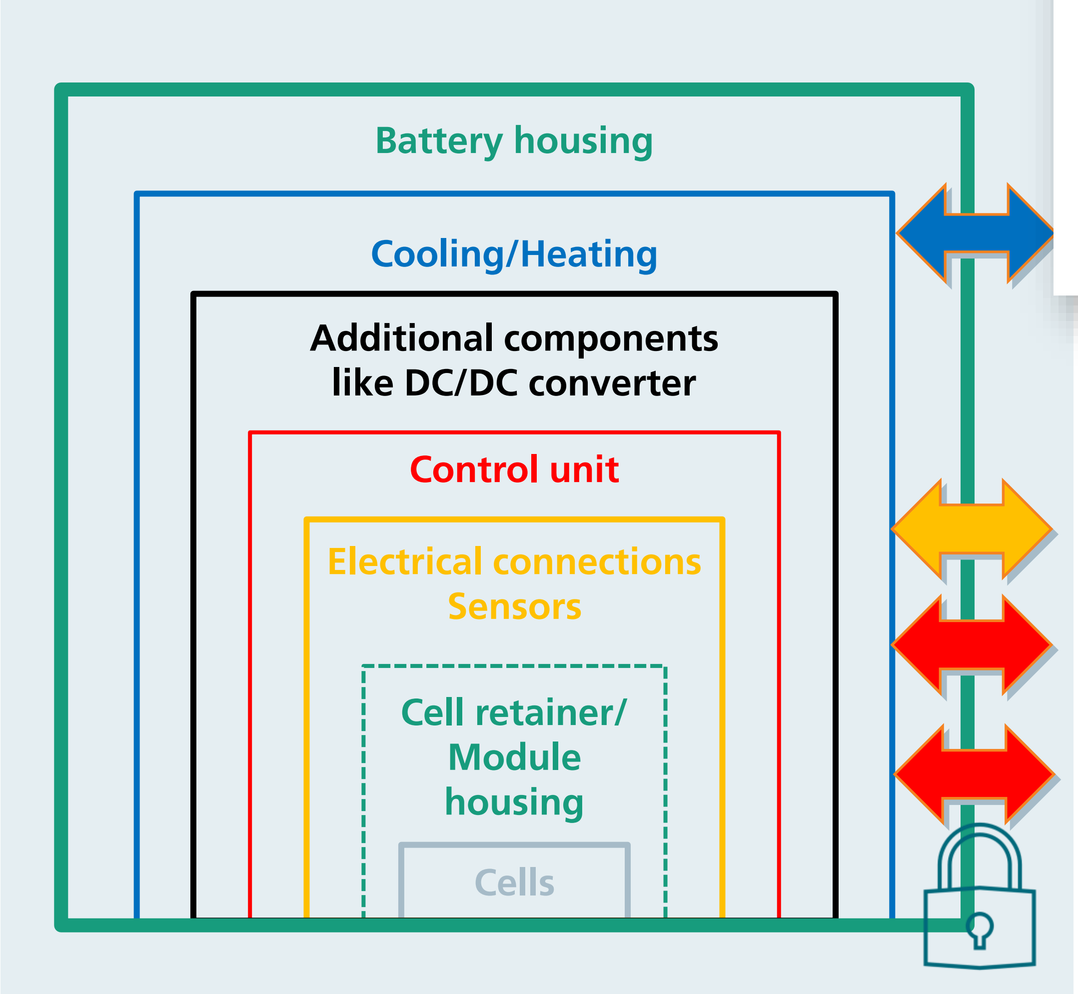
9	Cooling type	9.1	No cooling	9.2	Passive cooling	9.3	Active cooling
10	Heating type	10.1	No heating	10.2	Active heating		
11	Media	11.1	Air	11.2	Liquid	11.3	Gas
		11.4	PCM	11.5	Heat pipe		
12	Cell cooling surface	12.1	Cell side (single)	12.2	Cell side (double)	12.3	Cell bottom
		12.4	Tap cooling	12.5	Immersion		

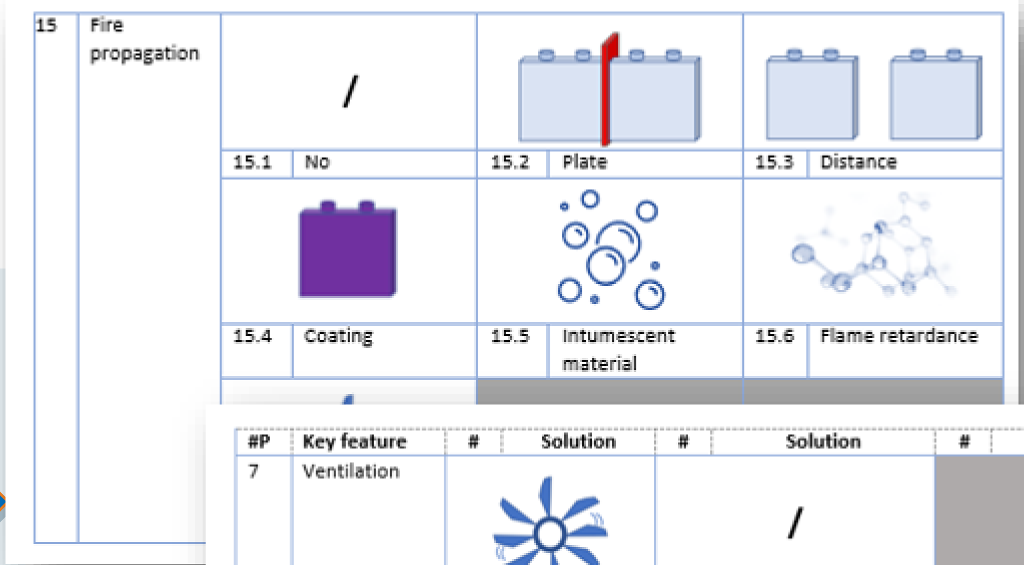
SEA BAT

Fraunhofer LBF

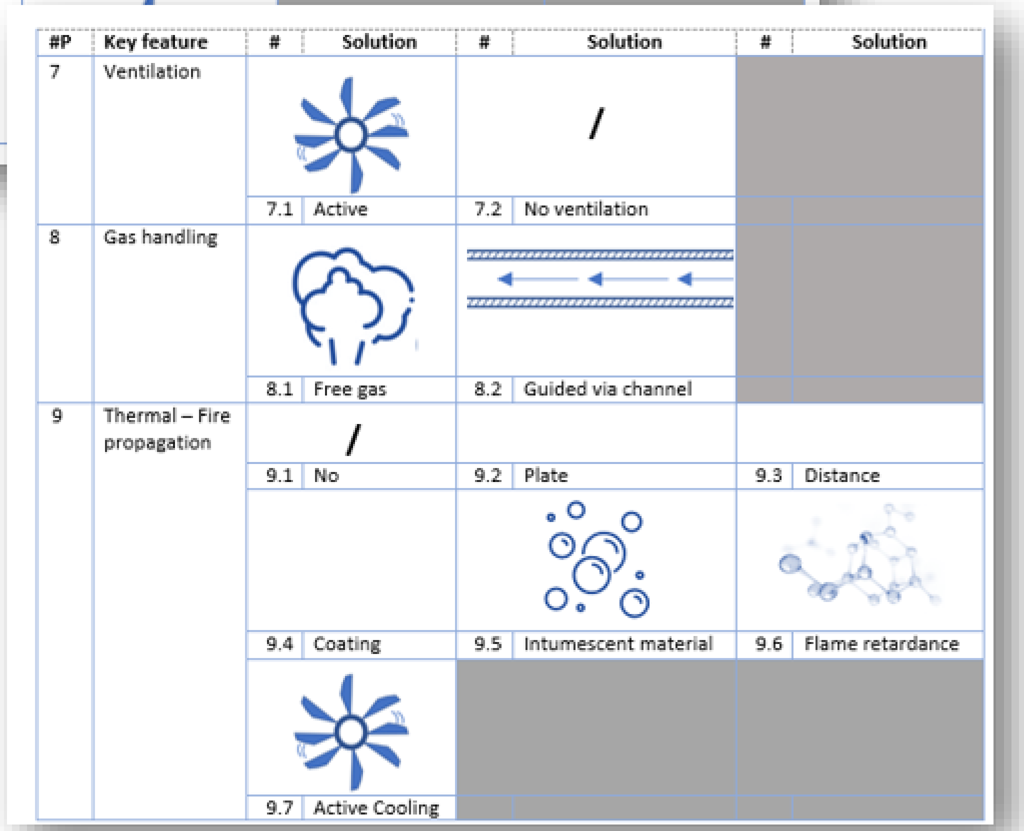
Architecture

Components



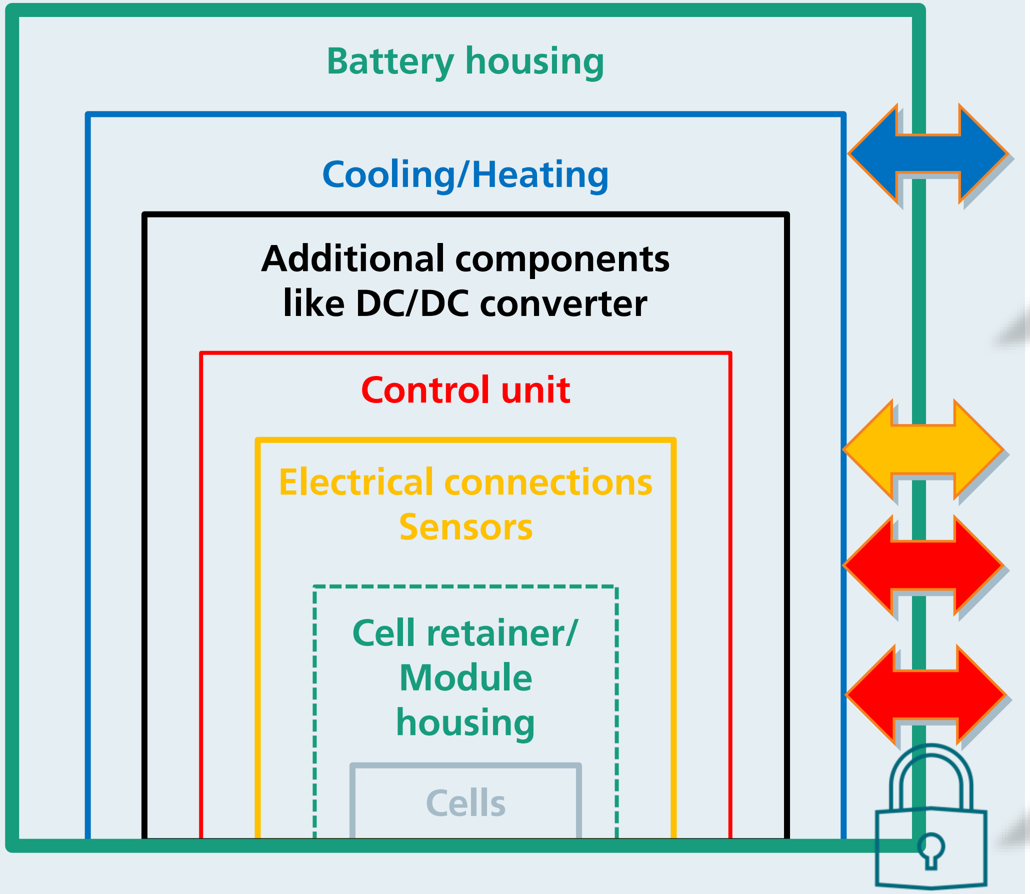


		#	Solution	#	Solution	#	Solution
15	Fire propagation	15.1	No	15.2	Plate	15.3	Distance
		15.4	Coating	15.5	Intumescent material	15.6	Flame retardance



#P	Key feature	#	Solution	#	Solution	#	Solution
7	Ventilation	7.1	Active	7.2	No ventilation		
8	Gas handling	8.1	Free gas	8.2	Guided via channel		
9	Thermal – Fire propagation	9.1	No	9.2	Plate	9.3	Distance
		9.4	Coating	9.5	Intumescent material	9.6	Flame retardance
		9.7	Active Cooling				

Requirements



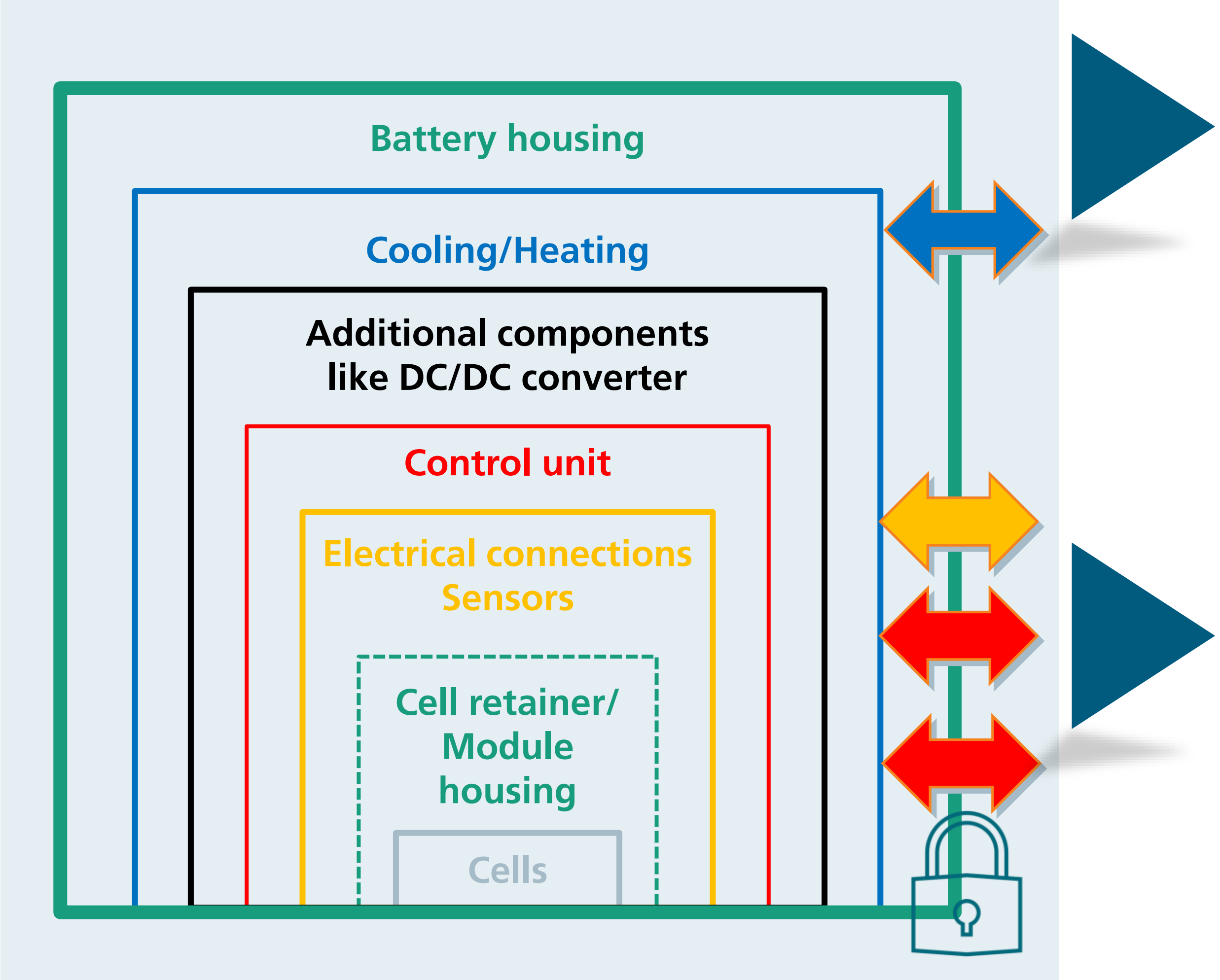
The **battery space** shall be **adequately ventilated** (to prevent accumulation of flammable gas) **and cooled** in such a way as to maintain the specific set of environmental design conditions.

The battery space shall be dedicated to **batteries only**. Not to contain other ship systems supporting essential or emergency services, including piping and electric cables serving such systems, to prevent their loss upon possible failures (e.g., thermal runaway) in the battery system.

The battery space is **normally unattended**.

10-year lifetime should be the minimum required design life. The systems are to be designed to maximize their lifetime.

Requirements

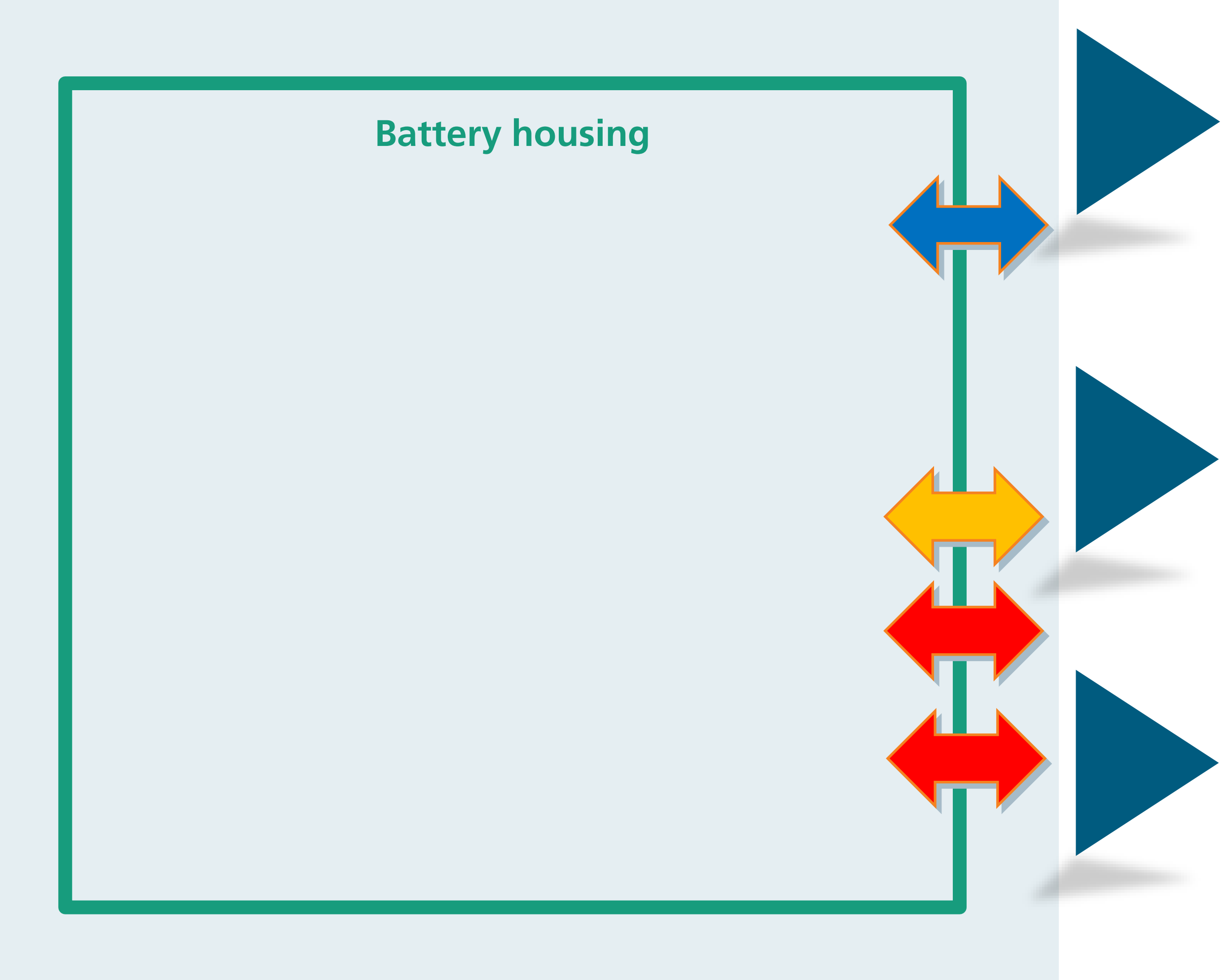


Cells are to be assembled in **suitable crates or trays equipped with handles** for convenient lifting and handling.

Battery stands, boxes and lockers **shall be fixed** to the vessel's structure, shall be constructed to **with-stand the forces imparted** from the batteries, **during heavy sea**. Systems shall be constructed to withstand ship **accelerations and inclinations** in accordance with applicable Class rules.

The system must be able to withstand vibrations **without any rupture, electrolyte leakage, fire or explosion**.
Energy storage systems shall be designed in compliance with Class rules to withstand ship vibrations without any adverse consequence.

Requirements

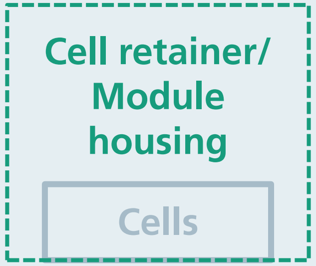


For the material used on the batteries shall be made of a **flame-retardant material** according to international **Rules IEC 60092-101**.

The battery space must be equipped with a fire detection and extinguishing system. The most important purpose for a fire extinguishing system in a battery space is the ability to cool, to prevent the fire from igniting the batteries. Battery systems equipped with water mist **system should have a minimum IP rating of 44**, but **preferably IP 67**.

The casing of a lithium cell and/or battery module is to incorporate a **pressure relief function(s)** that will prevent overpressure, rupture or explosion of the battery module enclosure.

Requirements



Regarding safety of the battery system, it is recommended to have **cell level thermal runaway propagation** measures.

Battery cells shall be placed so that they are **accessible for maintenance and replacement**.

Batteries are to be arranged such that each cell or crate of cells is **accessible from the top and at least one side.**

Mechanical design and validation

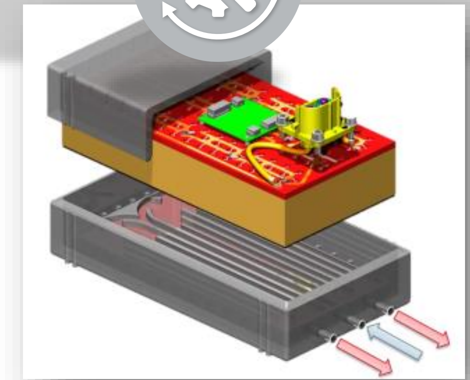
Requirements
- General
- Detailed
- From or for ship
- From or for battery system

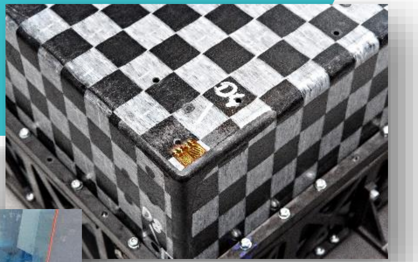
Architecture
- Main components
- Package
- Best volume use
- Best practice analysis assembly

Design
- Preliminary design
- Material selection
- Final design
- FE simulation

Hardware
- Prototyping
- Manufacturing
- Assembly (analysis)

Validation
- Material tests
- Components test
- System tests

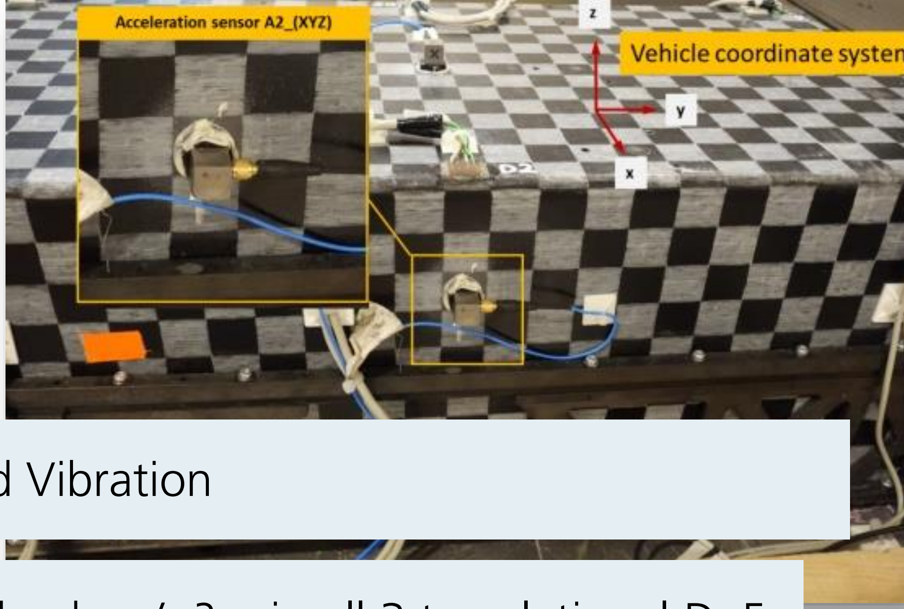




Validation at lab level

- Impact test (IEC 62619 7.2.2)
- Shock and Vibration
- Drop test according to IEC 2619 7.2.3
- IP verification, as declared by the Manufacturer according to IEC 60529
- Propagation test and gas analysis according to Class Rules

Validation at lab level



Shock and Vibration

- Shock: +/- ?g, in all 3 translational DoF
- Vibration profile: ISO or real profile?
- Vibration profile: uniaxial or multiaxial?
- Dummy cells or real cells?

Thank you for your attention!

Contact information:
Eva Stelter

Tel. +49 6151 705-8265
vorname.name@fraunhofer.de

Fraunhofer LBF

Bartningstrasse 47

64289 Darmstadt, Germany

www.fraunhofer.de