DYNAMIC REGULATION OF OPERATING PRESSURE AND TEMPERATURE TO IMPROVE NEXT-GENERATION BATTERY PERFORMANCE

Next-generation batteries, including lithium-ion (Li-ion) batteries, require pressure to operate. The operating pressure applied to a cell (stack pressure) influences several aspects related to its performance. The value of the operating pressure applied to the cells is important, but its uniformity is critical, especially when the cell volume changes during cycling (cell breathing) and when its structure evolves over successive cycles. The choice of principle for applying this pressure is therefore crucial in order to make optimum use of next-generation batteries.

OPERATING PRESSURE APPLICATION

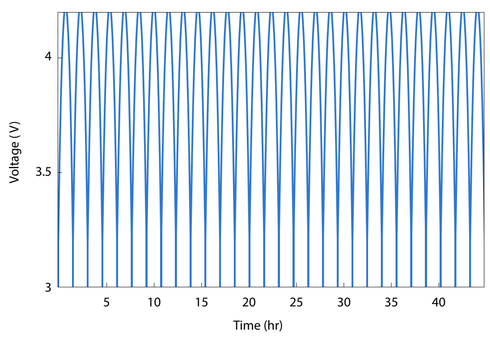
OPERATING PRESSURE

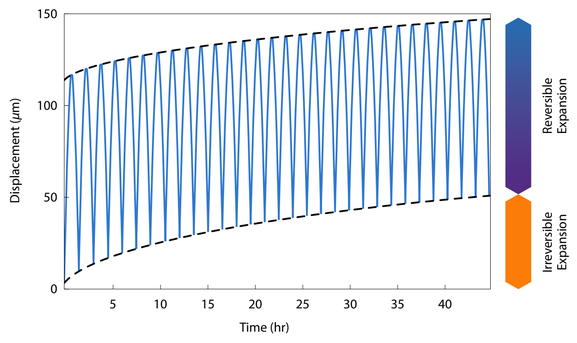
- The pressures applied during manufacturing and assembly are different from operating pressure and have a significant effect on cell performance. They also have a direct impact on the operating pressure to be applied.
- Operating pressure values vary greatly depending on the chemical composition used, including the type of electrolyte (liquid, polymer, oxide, sulfide, hybrid, etc.).
- More and more credible players in the development of solid-state batteries AND the automotive industry agree that it would be advantageous in some cases to dynamically adjust the operating pressure.
- The business case (the possibility of a niche) for a dynamic pressure regulation system still needs to be made in relation to the following issues: improving performance in terms of specific energy, energy density, cost and complexity.
- Hydro-Québec holds the intellectual property associated with these systems, which take the form of laboratory equipment and battery modules.

BACKGROUND

The operating pressure applied to a cell influences several aspects related to its performance, producing the following effects:

- Minimize the occurrence of dynamic porosity in fast discharge conditions.
- Promote a dense and uniform lithium deposition.
- Increase the charging speed without damaging the cell.
- Increase the life of the cell.
- Promote the quality, integrity, and stability of the cathode–electrolyte–anode interfaces.
- Enable controlled creep and improved lithium diffusion.
- Minimize the variations in cell volume.
- Minimize crack propagation.
- Minimize dendrite propagation.



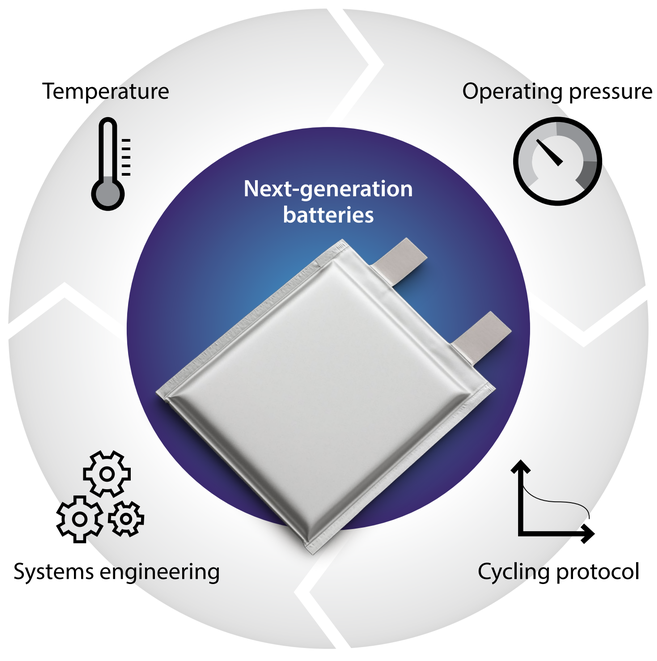


INNOVATION PROGRAM – SMART BATTERY

SMART CYCLING PROJECT

Measure, understand, control, and leverage the effect of pressure and temperature parameters on the performance of solid-state batteries.

Design high-performance, implantable systems that harness the exceptional capabilities of solid-state batteries.



INNOVATION STRATEGIES

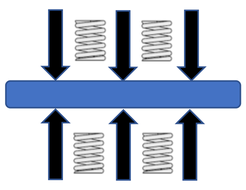
Develop innovative cycling tools: cycling housings (mechanical, hydraulic, pneumatic), a hydraulic servo system (pressure, temperature), cycling control software, and AI-based algorithms.

Cycle cells of all formats and technologies:

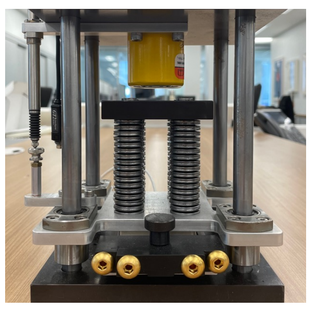
- Use standard charging protocols and establish benchmark performance levels.
- Develop innovative operating protocols to determine optimal cell operating parameters.
- Simulate highly demanding operating conditions in charging and discharging using protocols from the automotive industry.
- Use and combine charging protocols recognized for their performance benefits in batteries (self-healing, pulse charge).

Develop early concepts for the development of battery modules to make use of these research results.

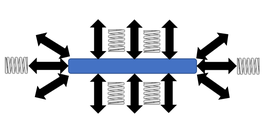
Conventional approach to pressure application



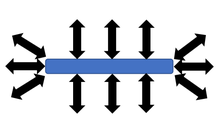
Compression plates with flexible components (springs)
- Uniaxial pressure
- Compressible
- Cell breathing (volume variation) possible
- Near-uniform pressure diagram
- Exact pressure value



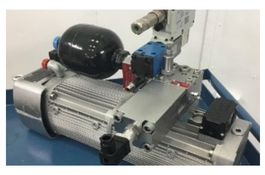
Innovative approaches to pressure application

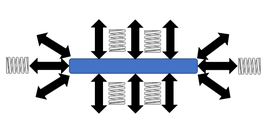


Pneumatic pressure – isostatic
- Compressible fluid
- Cell breathing possible
- Guaranteed uniform pressure diagram
- Exact pressure value



Hydraulic pressure – isostatic
- Incompressible fluid
- Cell breathing not possible
- Guaranteed uniform pressure diagram
- Exact pressure value

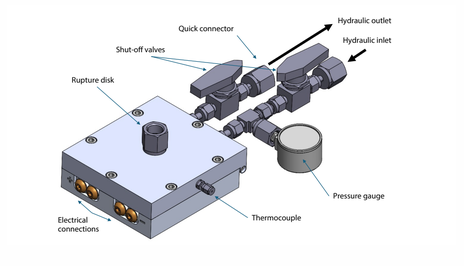


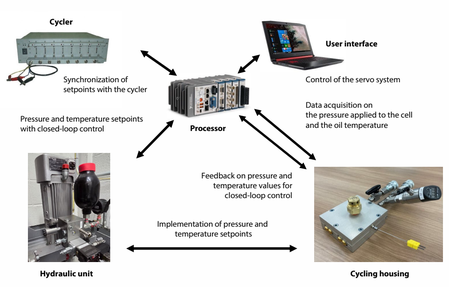


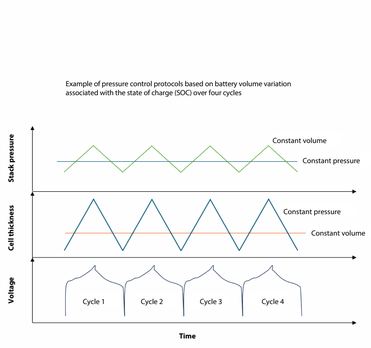
Regulated hydraulic pressure – isostatic
- Incompressible fluid
- Cell breathing adjustable
- Guaranteed uniform pressure diagram
- Exact pressure value

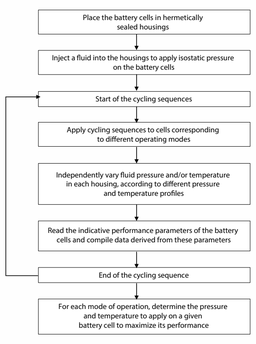
SMART CYCLING SYSTEM (SCS)

R&D SYSTEM – DEVELOPMENT OF NEW TECHNOLOGIES









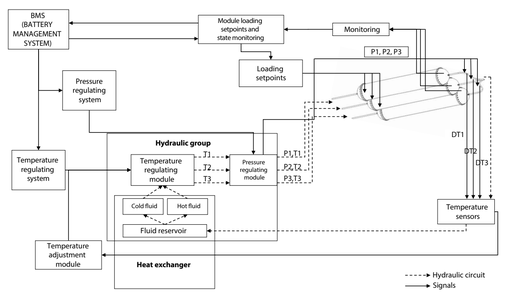
Preliminary results

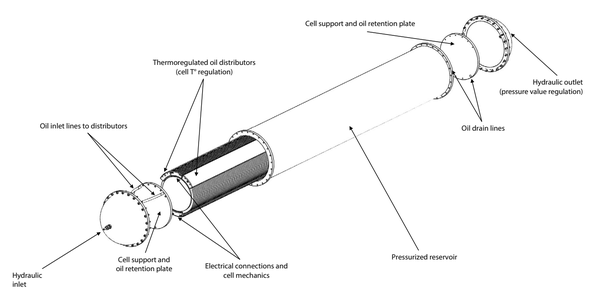
- Operating pressure (value, uniformity and means of application) is critical to cell performance.
- The SCS makes it possible to determine the operating parameters that optimize cell performance (pressure and temperature).
- The SCS enables the dynamic adjustment of these parameters during operation according to the load conditions (charging and discharge rates).

Enhanced safety

- Safety tests carried out on a 1-Ah polymer-electrolyte battery produced thermal runaway when performed with conventional cycling housing (compression plates) and pneumatic models.
- Under the same testing conditions, the hydraulic cycling housing created a cycling environment that helped prevent (or delay) thermal incidents.

COMMERCIAL SYSTEM – BATTERY MODULE





CONCLUSIONS

The SCS provides efficient and accurate pressure and temperature control to improve battery performance and safety:

- Allows the determination of optimal operating pressure and temperature values for any cell chemistry (use as R&D laboratory equipment).
- Provides real-time optimal operating parameters to maximize battery performance (use as a battery module):
  - Faster charging and discharge speeds;
  - Higher coulombic efficiency;
  - Longer service life;
  - Enhanced operational safety;
  - AI-based control algorithms.

Patents

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