DQE Battery Container – Operation

Dan Casey, CEO

Gordon Pace, Technical Advisor

Battery Container Assembly Overview

Dragon Q Energy’s (DQE) battery container is a fit-for purpose, large-format stationary storage device designed for grid and micro-grid stationary storage applications (Fig 1). We view this housing as “fit for purpose” in that cost, safety, and environmental impact are prioritized. This may sound like an intuitive goal for stationary storage, but it is actually not the standard. According to the EIA, over 90% of operational large scale battery storage utilize a lithium-ion chemistry. These typically take the form of thousands of small cells (such as cylindrical 18650’s designed for mobility applications) stuffed in a white box. Effectively, cells designed for consumer electronics and electric vehicles are strung together to form massive packs and modules. “Fit for mobility” formats are being incorrectly applied for stationary storage. This is done as a matter of commercial convenience; these small cells are already produced at scale for other applications. However, they are not well suited for large scale energy storage, being unreliable, expensive, and prone to catching fire.

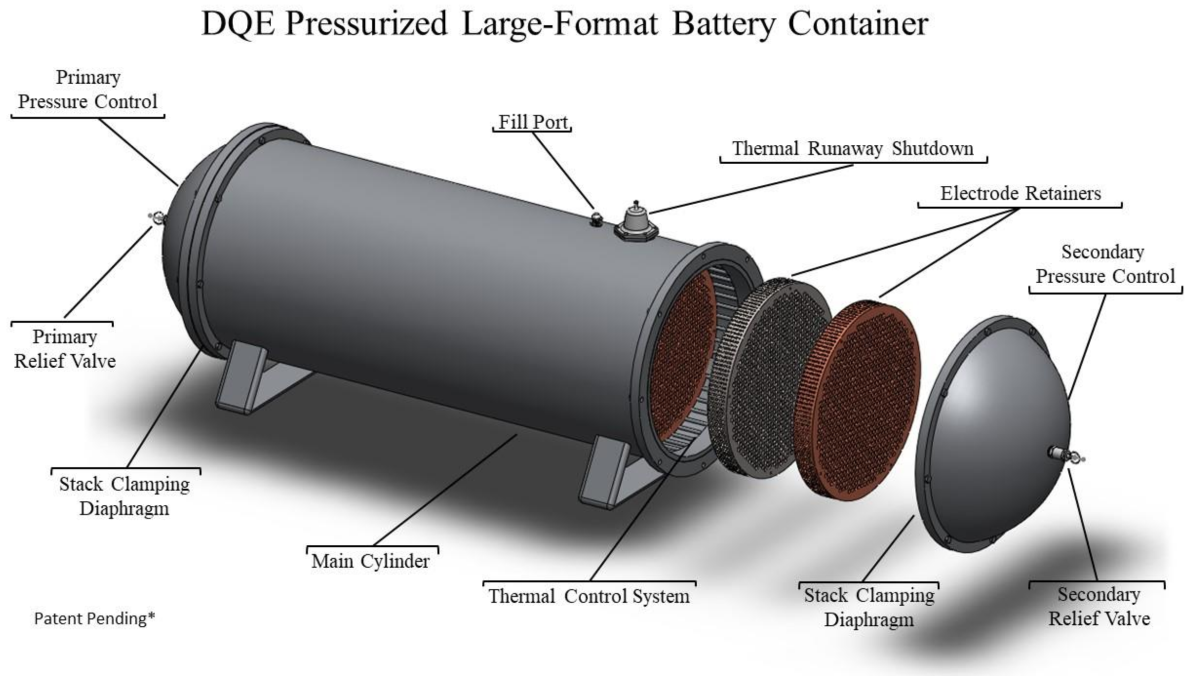

Figure 1. A schematic of the overall battery housing, containing a cylinder which allows for modular installation of large-format electrodes. The cylinder is equipped to provide large compressive force to this electrode stack to minimize interfacial and contact resistance. End caps and pressure relief valves allow for dynamic pressure control, improving both battery operation and safety. At the end of life, this format enables easy disassembly, allowing for improved recyclability of electrode materials and reuse of the main housing.

DQE has identified that the benefits of both pressure and electrode compression can address the issues of reliability, price, and safety, but the implementation of pressure as a “controlled thermodynamic knob” has been limited to academic literature. A suitable and scalable platform has yet to be developed. This is the vision for DQE’s container. Ultimately, we view our system as a platform which can be applied to numerous battery chemistries, and perhaps other electrochemical cells (i.e. fuel cells) in the future. Initially, we have focused on improving energy, power, cycle life, safety, and recyclability of large format, intercalation based rechargeable batteries, focusing on LFP cathodes coupled with graphitic anodes. Our fit for purpose housing will leverage compression and pressurization to improve safety and performance of these materials in large scale systems.

Beyond performance, our container is engineered with sustainability and recyclability in mind. First, the container itself can be disassembled via removal of the end caps. Modular electrode retainers can then be removed, enabling the materials to be recycled and the container itself to be reloaded with fresh electrodes. This provides for easy adoption of novel chemistries as battery materials progress and can also allow the housing itself to have an extraordinarily long operational life (50+ years).

Additionally, our system can enable thick format, free standing electrodes compressed onto current collectors, as the high level of stack compression will provide good interparticle and interfacial contact with the current collector, metrics which are currently achieved via ultra-thin (50-100 um) electrodes blade coated directly onto current collectors. The standard, coated electrodes are difficult to separate from current collectors at end of life, complicating recycling. Free standing, thick format electrodes enable easy disassembly and facilitate recycling (as well as lower upfront cost via reduction of ancillary components such as current collectors and separators).

Further details on how our container accomplishes these goals are outlined below.

Main Cylinder: The bulk of the battery housing is a cylinder with structural integrity that withstands high pressurization. The initial design proposes a metal housing with an insulated lining to balance strength and electrochemical stability. Composites or plastic materials can be used based on customer needs, internal chemistry, external environmental requirements, dimensions, weight etc. Because of the large-format, the container is designed to handle significant static and dynamic loads and would be considered a structural member. This opens the door for simple yet novel safety measures such as burying the cell underground, which would both provide thermal management and protect the battery in the case of fires or other natural disasters. Further, the container could serve as frame or chassis member within a cell-to-frame (CTF) or cell-to-chassis (CTC) EV integrated battery design scheme.

End Caps: The end caps seal the main cylinder, closing off the housing to create a battery container that is effectively a pressure vessel. The main method to attach the endcap to the main cylinder is by a bolted flange and the connection is serviceable for inspection, maintenance, and repair. Additionally, the split line between the end cap flange and the main cylinder flange can be sandwiched with a diaphragm of suitable material to apply, and translate, associated pressure to the main cylinder creating the primary and secondary expansion areas (Fig 2). The main cylinder, end caps, and diaphragms creates three distinct and separate compartments for chemistries and pressures. Flange fasteners may be a desirable place to attached mounting brackets for horizontal and vertical applications, or integration with a structure, and there are electric vehicle CTF and CTC applications.

Flanges: The main cylinder and end caps have flanges on each end of the cylinder to allow for installation of the end caps. Removable end caps improve accessibility to internal parts and provides a route to simple and effective maintenance, recycling old chemistry, updating container with future chemistry systems, and replacement of internal parts.

Pressure Ports: A port in the main cylinder and end caps (Fig 1) will allow for pressure of the of the main cylinder and pressure control areas to be filled and/or adjusted with the desired liquids and gases for any battery chemistry. The port may be finished with a shutoff valve and pressure-relief valve. Based on the specific battery chemistry utilized and installation requirements, the battery management system (BMS) may change pressure through the port during storage, charge, and discharge or under/over temp conditions. The pressure ports also enable low cost, large-format cell assembly, particularly for widely used Li-ion chemistries. Ultimately, the final Li-ion cell needs to be air and water free. This is currently accomplished by assembling small (i.e. 18650) cells in expensive, oxygen/water free environments (gloveboxes/dry rooms). With DQE's hermetic pressure vessel housing, we can assemble the electrodes in ambient conditions, then attach a vacuum to the pressure ports to remove all ambient gas prior to infiltrating with electrolyte and closing the fill port.

Pressure Relief Valves: The end caps creating the primary and secondary expansion areas will each have a pressure relief valve to release any over-pressure from thermal runaway events while maintaining the integrity of the container and chemicals to the main cylinder. In the event the primary and secondary pressure relief valves do not mitigate a thermal event, a third pressure relief valve, and ultimate fail-safe will depower the main cylinder of chemicals and shutdown any thermal runaway events. This prevents catastrophic failures of the container, fires, and explosions.

Pressure Control: The primary and secondary pressure control and relief areas are formed by clamping a diaphragm between the main cylinder flange and the flange of the end cap. The area in the end cap is chemically isolated from the main cylinder yet allows pressures to be transferred between the separated chambers. This serves as a damper or pressure accumulator, creating a consistent operating environment inside the battery container by adjusting for diurnal and seasonal temperature changes, solar heating, and other factors (Fig 2).

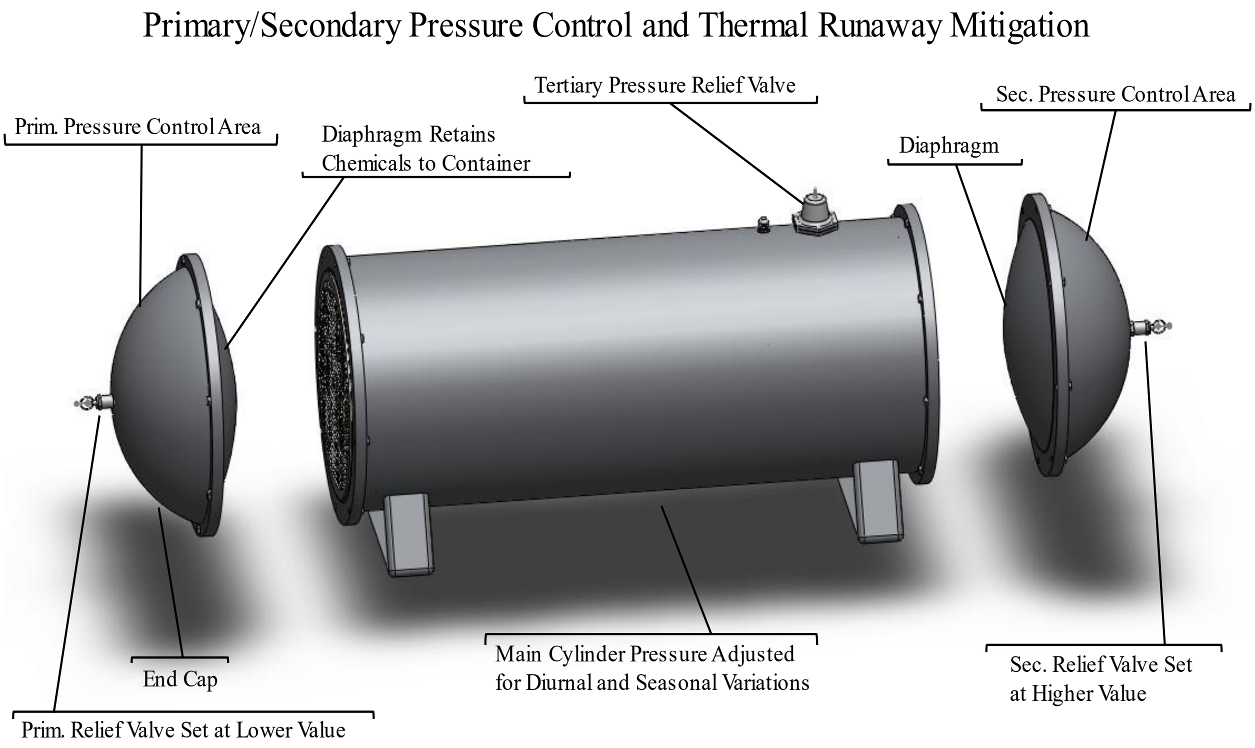

Figure 2. A schematic of DQEs housing emphasizing the pressure control systems. Flexible membranes in the ends caps allow for dynamic expansion and contraction to maintain potimal pressure as environmental conditions change. Pressure relife valaves allow for control in the event of a catostrophic failure, mitigtaing the risk of fire and explosion.

Electrode Retainers: Electrode retainers provide a modular, systematic, way to install novel large-format electrodes into the battery container assembly, where electrodes, current collectors, and separators can be layered into retainers. The retainers and electrode material inside the retainer can be arranged in series and/or parallel for different voltages and currents desired. This facilitates the same housing format to be fitted for a breadth of use cases. The retainers also support a modular approach for repair, maintenance, updating, and recycling of old electrodes at their end of life.

It should be noted that the battery main cylinder can be configured to operate with or without the use of electrode retainers installed inside. The retainers simply offer an easy method for battery engineers and chemists to insert proprietary battery chemistries of cathodes, anodes, and electrolytes. It may be desirable to use existing industry electrode manufacturing processes, tooling, and films manufactured at gigafactories, etc. Particularly, we have envisioned a strategy for a free standing thick electrode pellet constructed of recycled electrode precursor material, then installed in a perpendicular retainer (Figure 3) that may be more amendable to manufacturers not equipped for standard foil electrode production.

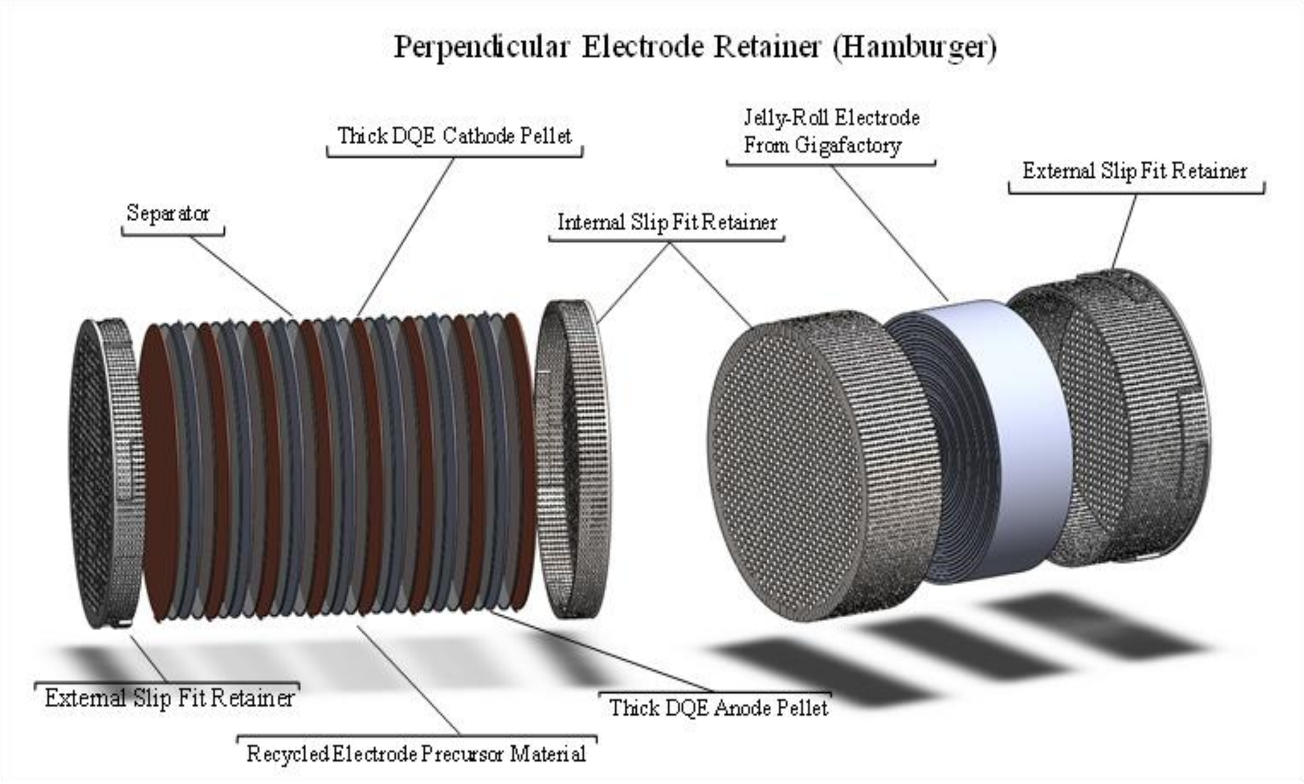

Figure 3. A few manifestations of our retainer mechanism for modular electrode assembly, where retainers containing electrode stacks can then be connected in series/parallel as desired. On the left, free standing, large format, pellet electrodes are stacked along with current

collectors and separators. Free standing electrodes enable easy manufacturing, straightforward post-life recycling, and a reduction of the total number of current collectors and separators (reducing cost and increasing cell level energy density). We envision this as the most impactful electrode format that is enabled by our container. However, many manufactures are already equipped to produce jelly-roll format electrodes (right) and developing a retainer compatible with these will enable rapid adoption.

Cell Stack Clamping: It is well understood by battery engineers and scientists that providing a clamping force to a cell will instantly increase cell capacity and reduces degradation of cell components due to improved interparticle and interfacial contact, reducing resistive loses and overpotential. The DQE container is purpose-built to provide significant clamping force (compression) to the retainer and electrodes. The container design achieves this in several aways:

- By applying a greater air pressure to the primary and secondary expansion areas, the resulting force on the diaphragm or membrane translates that force to the main cylinder and cell stack from both sides. This clamping force acts in a longitudinal direction to the main cylinder body.

- With electrode retainers, the slip-fit feature and an “over-fill” process can be utilized to translate a clamping force through any size stack of retainers. This method to generate the force can be created as the retainer and end caps are fastened and torque is applied, thereby squeezing the slip-fit retainers together.

- The main cylinder walls are designed to resist the radial expansive forces of jelly-roll applications as well. On initial installation, the jelly-roll can be super-cooled and interference fit in the main cylinder. As the jelly roll warms to ambient temperatures, it will already be experiencing significant clamping forces.

Clamping Force Mechanism Detail

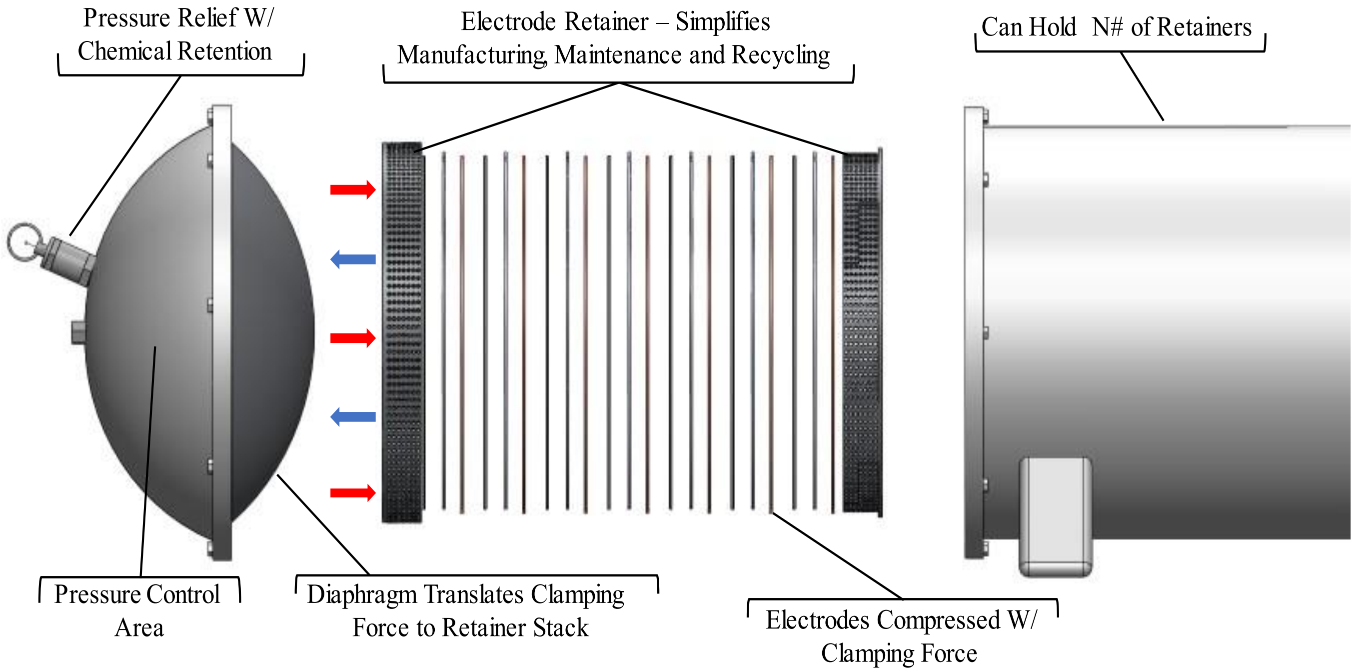

Figure 4. Our housing is engineered to provide extensive clamping force to electrode stacks, improving interparticle contact, reducing resistance, and creating an overall more efficient cell.

Geological Thermal Management: This is a first-of- a-kind buried long-duration energy storage battery. The large-format, vessel style, and long cycle-life is conducive to burying the battery container underground. This robust sub-terrain installation smooths out the battery thermal management requirements for diurnal, seasonal, solar heating, and radiative heat losses, etc. Although thermal management related to internal electrical resistance and charging still needs to be addressed, the consistent temperature experienced just under the surface of the earth provides a more desirable, stable, environment for battery operation. This also provides the added safety benefit of reduced exposure to natural disasters, terrorism, or other extreme weather events that could damage the cell.

Passive Thermal Management: For stationary above ground installations, the battery container will be made of a thermally conductive material to allow heat to leave the container via radiative cooling.

Active Thermal Management: The large format cell housing also allows space for additional, active thermal management devices to be installed, which are not feasible in smaller cells currently being implemented for EV and BESS. For instance, a closed-loop system with internal channels, pipes, and plumbing can be installed to allow a cooling fluid to be circulated to the internal portion of the battery. Heat is transferred from the battery to the cooling fluid, and then routed to external cooling units and heat exchangers to transfer the heat to the atmosphere. In most instances, this could be accomplished simply with cooling water, analogous to what is done for thermal management of industrial chemical reactors.

Ultimately, built in, robust thermal management will further stabilize the electrolyte, active materials, and interfacial layer, enabling long cycle life for our large format BESS.

Interoperable Battery Systems: Beyond the scope of this fundamental white paper on the operation of the chemistry agnostic DQE battery container it should be emphasized the patent protected container is infinitely configurable as a current and future test-bed for battery system innovations such super-capacitor, pressurized metal-air, pressurized redox-flow, fuel-cell, and electrolysis applications… even a pressurized Metal-Air Flow Battery. This keeps us excited every day.

Pressurized Metal-Air Battery