Creating Power Distribution Solutions in an Electrified World

Jim Dawson Vice President of Engineering and Technology at Royal Power Solutions, introduces two breakthrough products – High Power Lock Box (HPLB) terminals and RigiFlex™ busbar systems. These green technologies improve energy efficiency and minimize wasted energy in electric and hybrid vehicles.

These two products have achieved concept approval on 22 vehicles during development in Europe and the United States. HPLB and RigiFlex will be utilised in production vehicles for (4) NAFTA OEMs scheduled for 2022.

A ground-breaking high-current, high-vibration and high-temperature terminal family for LV, HV and 48-volt applications.

High Power Lock Box (HPLB) Terminals

The High-Power Lock Box (HPLB) system is a patented multiple contact terminal system that provide ultra-energy efficiency through lower resistance. HPLB is the industry's only high current terminal system (above 150 amps continuous current) that meets USCAR2 T4 (150° C) and V4 (severe vibration) requirements while also capable of S3 standards for sealing under pressure spray when contained in a sealed connector system.

HPLB terminals solve many problems that the hybrid and electric vehicle industry has encountered in developing applications, enabling high-current connections able to withstand high-vibration and high temperature mechanical stresses while delivering a full system solution.

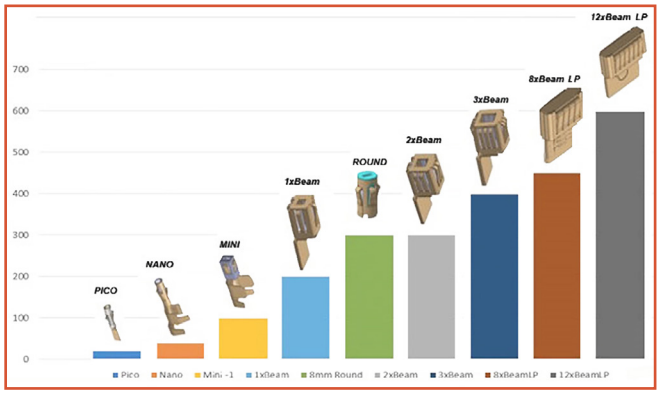
Critically differentiating in HPLB terminals are stainless-steel springs, which add to structural integrity and higher current carrying capabilities, creating less resistance and heat generation, thus improving efficiency. We refer to this as an *"ultra-energy efficient connection,"* which provides almost zero energy loss, at each terminal connection point, when measured during a Dry Circuit Resistance test. HPLB terminals reduce weight and provide an assembly cost and time savings on the plant floor.

HPLB terminals have been tested for use at elevated operating conditions defined by leading battery electric vehicle OEMs to further prove its robustness in application in the most challenging environments and applications.

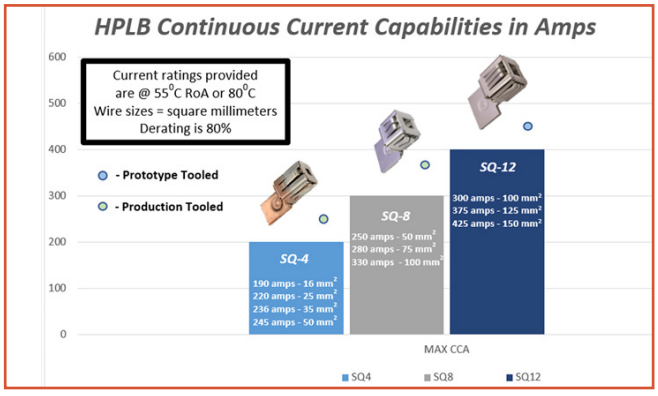
Features & Options.

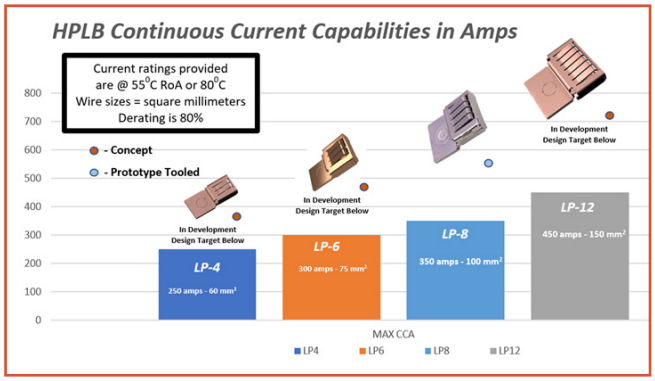
- Extremely High Current Carrying Terminal System
- T4 (150° C) / V4 (Severe Vibration) Capable
- Ultra-Energy Efficient System – No Loss
- Copper (Cu) or Aluminum (Al) available
- Space Savings
- Weight Savings
- Cost Savings
- Time Savings

SPECIFICATIONS & SIZING



HPLB – CONTINUOUS CURRENT CAPABILITIES





Rigid to meet design standards and Flexible to meet design needs.

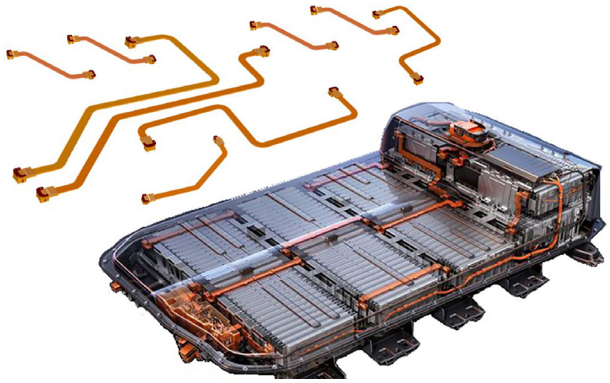
RigiFlex™ busbars

The RigiFlex™ busbar system in an ultra-efficient, durable, busbar system that is both rigid and flexible based on application requirements. The continuous, seamless conductor enables fully automated battery pack assembly. These systems utilize common conductor materials without butt or splice welds that can increase cost, resistance, and failure modes. The RigiFlex™ system is so efficient it can be "Daisy-Chained" within a module or pack design to simplify assembly and increase safety, without adding the resistance that causes energy loss due to heat generation.

This advanced solution supports green initiatives for the market and improves the safety and handling of critical high voltage energy storage and distribution systems. RigiFlex has nearly zero development time, no Die or Mold Tooling, and Zero Engineered Scrap.

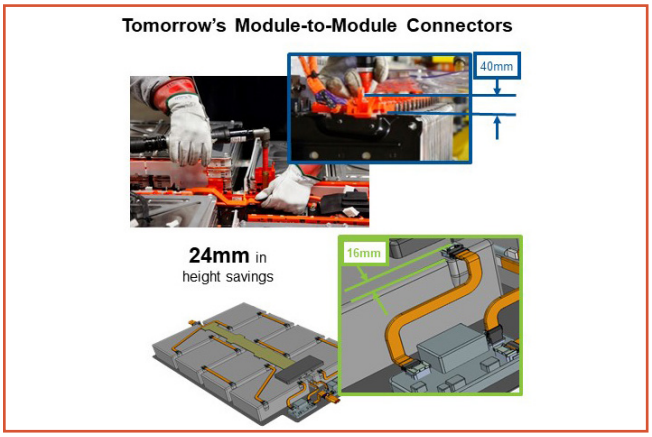
RigiFlex™ busbar systems can be combined with HPLB terminals, delivering a boltless conductor system which removes ferrous materials and inefficient welds that can create safety hazards in assembly and high resistance energy wasting hot spots.

The flexibility of this combined system overcomes stack-up tolerances and allows for more simple automation solutions at the customer manufacturing location.



RigiFlex busbar and HPLB terminal systems

With safety in mind, RigiFlex™ busbars combined with HPLB terminal systems enable automation to handle, articulate, place, and verify these busbars into modules or packs. Safety improvements are seen in production and service. In production, humans are removed from the assembly process which alleviates the possibility of shock or burn from a loose fastener causing a zero-resistance short circuit.

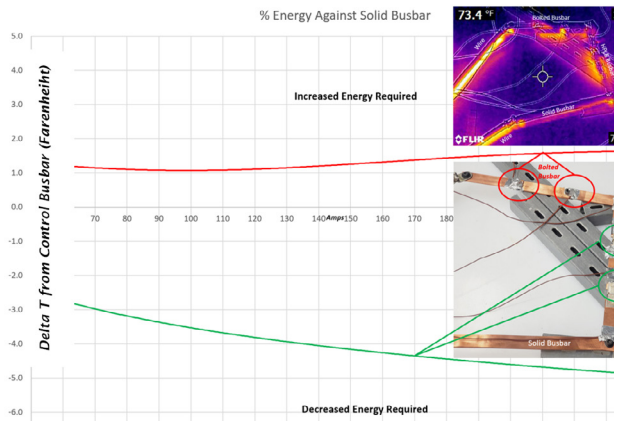


The push/click/plug mate solution nature of the RigiFlex connection system allows the copper contacts at the end of the busbar to be completely enclosed. This promotes safety by eliminating risks for inadvertent shock.

Additionally, serviceability becomes safer as the RigiFlex™ connection systems are finger-proof and easily serviceable via normal USCAR connector disengagement processes. Space constraints are another area where the RigiFlex™ connection systems out-performs typical, bolted busbars. On average, bolted busbars require 40mm of z-axis space; RigiFlex™ busbar systems only require 16mm to complete the same connection.

Major advantages of the RigiFlex™ busbar system:

- Space Savings - More active material/range in EV battery packs
- Ultra-Energy Efficient – Virtually no loss due to heat loss/mitigation.
- Sustainability – Zero Engineered scrap
- Ease of Connection – With optional HPLB Push-Click-Pull Connector Terminals
- Copper (Cu) or Aluminum (Al) Available
- Simplification of Production –
  - No Die Tool for Busbar
  - No Over-mold Tool for Busbar
  - No Tool Development Timing
  - No Loose Piece Nut on Mfg, Line
  - No CANNED Gun Air Equipment on Mfg. Line
- Largest cross-sectional area in market today
- T-shapes and 90-degree forms



RigiFlex™ busbar and HPLB terminal system vs. Traditional bolted busbars – test results

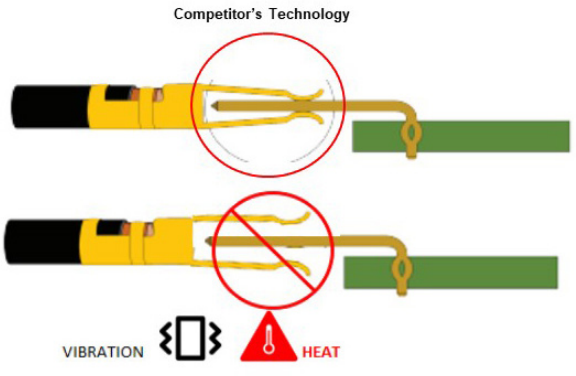
In recent tests, a control (solid) busbar system in a series was compared with HPLB terminals using RigiFlex™ busbars. The ends of this series busbar are each attached to 50mm2 copper wires which are connected to power supply and ground.

The test demonstrates that as 250 continuous current amps (CCA) are applied to this system, some interesting results are evident. As the test was conducted, RPS utilized its FLIR camera to depict the hotspots of the system and strategically place thermocouples at each connection to record accurate temperature readings during the test.

First observation:

At 250 CCA, there, is a 60 differential in operating temperature. This is a very significant operational advantage for HPLB over bolted busbars in Lithium-Ion battery packs that are cooled. The reduced resistance of current flow through the HPLB connections, compared to bolted connections, wastes less precious system energy in the form of heat. HPLB's lower operating temperature means the pack cooling system does not need to mitigate as much heat, resulting in valuable range addition.

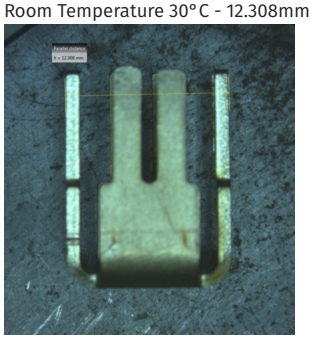
HPLB terminals and RigiFlex™ busbar connection systems allow for truly optimized energy connection systems – "Ultra-Energy Efficient Connection"



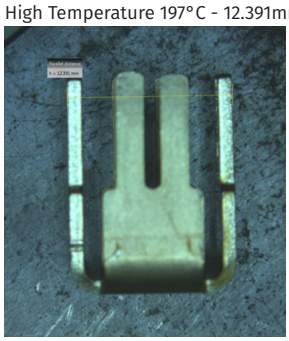
Standard Box & Blade designs only provide 2 points of contact and spring squeezes blade

Second observation:

Room Temperature 30°C - 12.308mm



High Temperature 197°C - 12.391mm

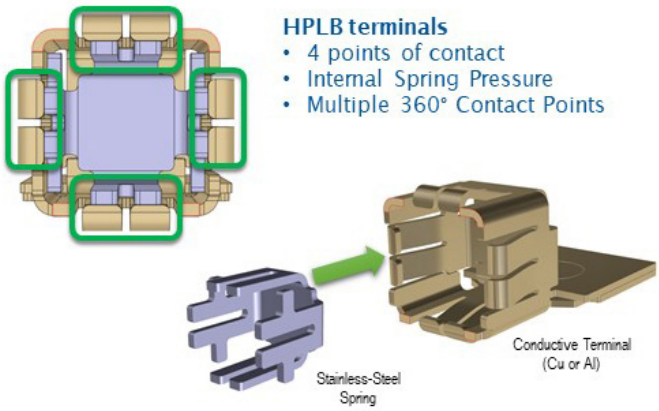


There is an inverse relationship between the bolted busbar and the RigiFlex boltless busbar in terms of heat generation. The bolted busbar continuously increases in temperature due to the constant resistance of the bolted connection. The HPLB connection decreases in resistance as the temperature increases. This is made possible because of the internal spring of this terminal's design. As the heat increases, the HPLB terminal's internal spring relaxes, increasing normal force of the connection thereby lowering the contact resistance. This phenomenon counteracts the consistent resistance/heat/temperature increases that must be endured in the bolted system.

Third Observation:

Busbars that are bolted together are not only less efficient, but they are also dangerous to assemble. Using again the example of a Lithium Ion traction battery pack, the modules are live during assembly of the pack. This means the assembly technicians must wear high voltage gloves to assemble the traditional module-to-module and module-to-device bolted connections.

HPLB terminals combigned with RigiFlex busbars facilitate the possibility of automated pack assembly due to their unique flexible and rigid ability to comply with manufacturing variances and module thermal expansion and contraction. Further, the space we require to make this connection is 60% less than a bolted connection, easily serviced without special tools and HPLB is not susceptible to vibration failure.



RigiFlex™ is a US trademark owned by Royal Power Systems. High Power Lock Box and RigiFlex are patented in the US and internationally with many other patents pending worldwide.