



**MAR-BAL DELIVERS COMPOSITE EV BATTERY ENCLOSURE
FOR WORLD'S FIRST 100% BATTERY-POWERED
HEAVY-HAUL FREIGHT LOCOMOTIVE**

OPTIMIZED TO MEET THE MOST DEMANDING EV REQUIREMENTS

Mar-Bal designed and delivered a custom engineered composite EV battery enclosure for world's first world's first 100% battery-powered, heavy-haul freight locomotive.



Specialized structural battery enclosures required to withstand extreme heat, explosion and prevent thermal runaway



Custom engineered composite solution designed to meet high mechanical and thermal performance requirements



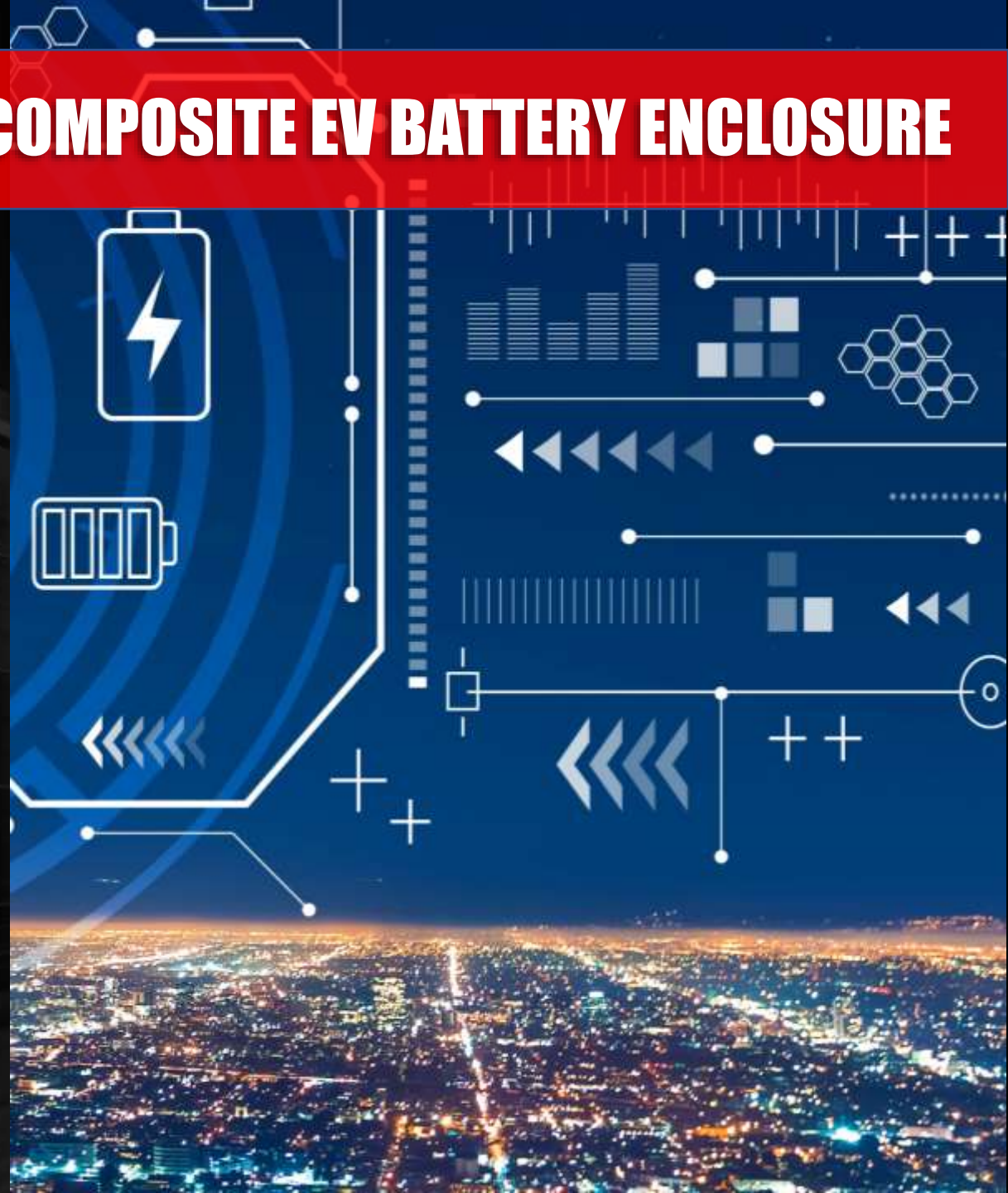
Development of first custom EV battery enclosures safely house over 600 locomotive battery modules at 2,400kWh

Designed to meet extreme performance requirements, these enclosures protect more 20,000 Lithium-ion batteries @ capacity = 2.4 Megawatt hours.



WABTEC COMPOSITE EV BATTERY ENCLOSURE

- Mar-Bal was tasked with delivering high performance battery enclosures for the world's first 100% battery powered locomotive.
- Wabtec required battery enclosures with flame retardant properties for their first fully electric locomotive.
- Physical property demands required battery enclosures to safely house 20,000 battery cells along with their electrical components.
- In collaboration with GE/Wabtec advanced engineering team, analyzed and set performance targets, prototype and test to arrive at custom developed and specialized requirements.
- Mar-Bal custom designed a material to meet flammability and high physical strain requirements without compromising modulus.
- The solution encompassed thermal management and runaway requirements safely containing 20,000 Lithium-ion battery cells, electronic modules and controllers managing energy storage and 2,400 kWh / 2.4 megawatt hours energy capacity.





WABTEC FLXDRIVE BATTERY LOCOMOTIVE AT A GLANCE

Wabtec's Battery-Electric Locomotive (BEL) pilot is part of a \$22.6-million grant project with BNSF and the San Joaquin Valley Air Pollution Control District.

- Capable as 100% electric or hybrid
- Reduces emissions by +10%
- ~20,000 Lithium-ion EV battery cells provide onboard energy storage
- 2,400 kWh energy capacity
- Produces up to 4,400 HP
- Regenerative braking + wayside charging
- Trip optimization w/Smart Cruise Control

Specifications

Energy Source	Lithium-ion Batteries	Charging	There are two ways the locomotive is charged: <ul style="list-style-type: none">• Wayside charging station, Stockton, CA• Dynamic braking during operation
Size of Battery Unit	20 racks, which consist of approximately 20,000 battery cells <ul style="list-style-type: none">* HVAC system to keep batteries at room temperature in all environments* Energy-management system to monitor battery health, charge rates and other conditions	Weight Maximum	Approximately 430,000 lbs
Energy Capacity	2,400 kilowatt hours	Maximum Speed	Approximately 75 MPH
Duration of Full 4400 HP output	30-40 minutes <ul style="list-style-type: none">* Recharges during operation through dynamic braking	Number of Axles	6 <ul style="list-style-type: none">* Battery to supply energy to all four powered axles
Emissions	Reduces the train's emissions by at least 10 percent.	Grant Partners	BNSF and the San Joaquin Valley Air Pollution Control District and the California Air Resources Board
		Test Date	Late 2020
		Test Route	Barstow-to-Stockton Route
		Route Length	350 miles

The company designed and built a full-size, 100-percent battery-electric freight locomotive featuring an overall energy-management system. This prototype was used for proof-of-concept and performance testing on BNSF's 350-mile Barstow to-Stockton, CA route.

Source: More information @ www.wabteccorp.com/locomotive/alternative-fuel-locomotives/flxdrive

COMPOSITE BATTERY ENCLOSURES FOR WABTEC FLXDRIVE WORLD'S FIRST 100% BATTERY-POWERED HEAVY-HAUL FREIGHT LOCOMOTIVE

Problem:

- How to safely contain 20,000 lithium-ion batteries with a capacity of 2.4 megawatt hours

How Solved:

- Developed an engineered high performance composite EV battery enclosures to meet flammability and high physical strain requirements without compromising modulus. These unique enclosures are able to contain potential explosion and prevent thermal runaway.

Benefit:

- Met and exceeded targets set by GE & Wabtec advanced engineering for performance.
- Enabling Wabtec to safely power the worlds first 100% electric locomotive.



Image source: www.wabteccorp.com