Aerospace & Defense Thermal Materials: From Lab to Field

THERMAL MANAGEMENT EXPO NORTH AMERICA

Molding Machines
for Complex Applications

Rick Fitzpatrick, X2F CTO & Founder



Thermally Conductive Structural Materials: From Lab to Scale

Every EV, inverter, battery system, data center, drone, radar, and power electronic system needs better heat removal—but also lower cost, lighter weight, and scalable production.

Problems Faced-

- *TC materials are highly filled, difficult to process in injection molding machines.*
- *Mineral fillers used for thermal management weaken polymer structures*
- *Woven carbon fiber lay-up does not scale, epoxies used are difficult to work with*
- *Carbon fiber lay-up does not address small part needs; smaller parts are machined alloys or molded plastic with no TC value*

Thermally Conductive Structural Materials: From Lab to Scale

X2F is using unique TC materials to encapsulate battery management system PCB's, controller boards and coils while also developing high-strength thermally conductive blends to combine functions, electronics thermal and mechanical protection, economically.

Problems Solved-

- *X2F is working with material suppliers and customers to develop thermally conductive, high-strength materials we/you can process*
- *Mineral fillers can be augmented with long carbon fiber that can enhance TC properties because the fiber is randomly distributed in 3 dimensions within molded parts.*
- *Long carbon fiber blends in thermoplastics, molded with X2F equipment offers isotropic strength with matrices while enhancing TC properties*
- *We provide product design services along with materials expertise to help designers reach goals in structures, thermal management and cost*

Aerospace and Drones

X2F replaces heavy, over engineered aerospace electronics assemblies with integrated, lightweight, and production ready solutions.



- **Materials freedom**

  Long carbon fiber in any base polymer, including thermally conductive blends, for metal replacement, light-weighting and thermal management

- **Stress free encapsulation**

  Preserve, protect and shield power electronics while protecting from the environment and providing heat spreaders

- **Part consolidation**

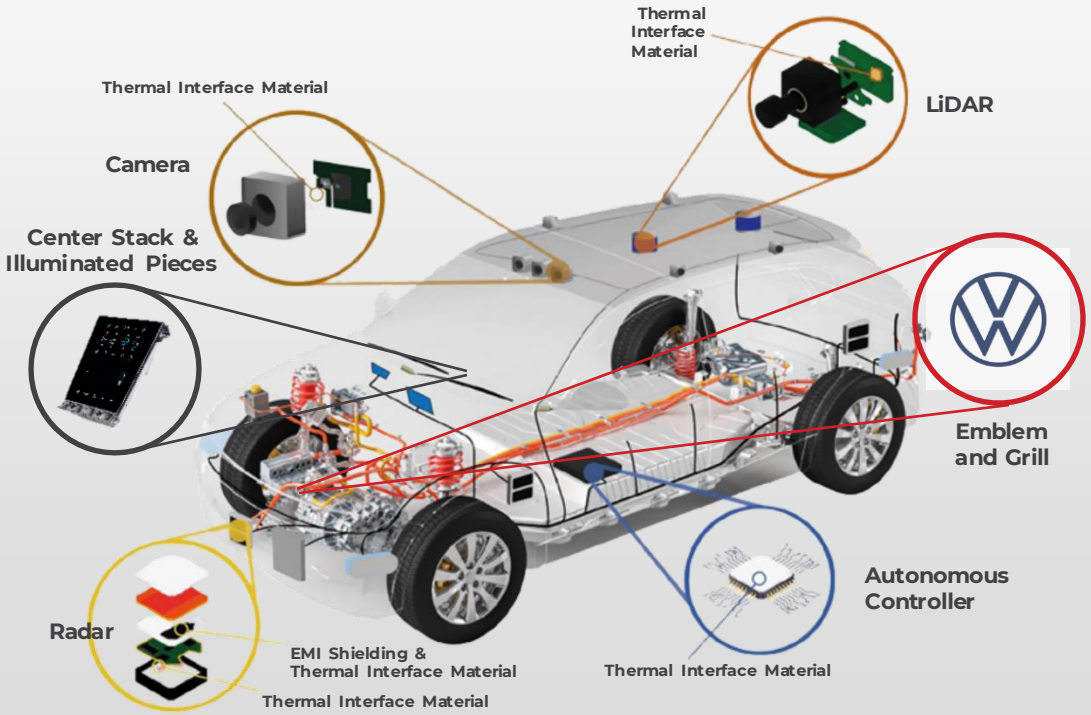
  Mate structural materials that are aluminum replacements with thermally conductive materials that are safe for PCB encapsulation to reduce part counts, assembly steps

- **Scalable, repeatable manufacturing**

  Use long carbon fiber in high-rate manufacturing, get strength and scale capabilities. Eliminate secondary hardware, epoxies, potting, coatings, and multi step sealing

Automotive & Mobility

The X2F process replaces multi part automotive electronic assemblies with integrated, low stress, and production ready molded solutions.



- **Predictable geometry and stable insert placement**

  Enables insulation, sealing, alignment, strain relief, and mechanical support to be molded directly into electronic components with repeatable dimensional control

- **Low stress encapsulation and over molding**

  Protect solder joints, windings, sensors, optics, and coatings while maintaining electrical, thermal, and environmental integrity under automotive operating conditions

- **Part consolidation**

  Reduces secondary hardware, stacked interfaces, adhesives, and tolerance accumulation while improving dimensional stability and long-term durability

- **Scalable, repeatable manufacturing**

  Eliminates multi step potting and cure time variability while supporting high volume production aligned with automotive cost, reliability, and throughput requirements

Defense

X2F uses specialized materials to harden electronics and shield components



- **Hardening electronics with thermoset**

  X2F uses thermoset materials to encapsulate electronics to seal them against the environment while increasing their lifespan when operating at elevated temperatures for extended periods.

- **Low stress encapsulation and controlled molding**

  Protect PCBs, solder joints, sensors and components, eliminate potting and coatings while maintaining electrical, thermal, and environmental integrity.

- **Part consolidation**

  Replace bracket stacks, secondary hardware, and multi step assemblies by integrating structural, shielding and thermal interface features into fewer molded parts.

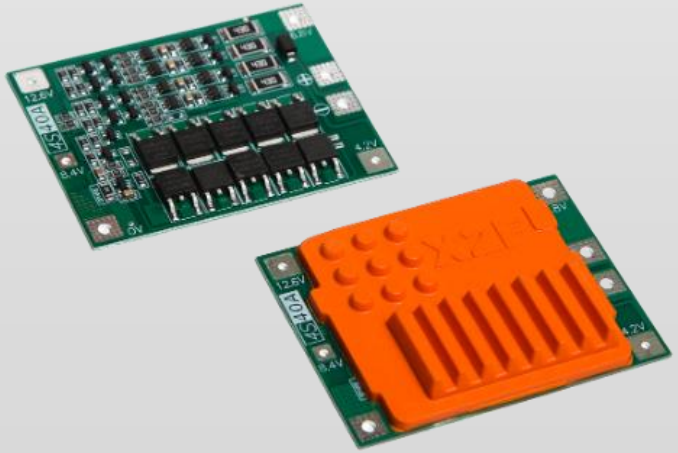
- **Scalable, repeatable manufacturing**

  Eliminate multi step potting and cure time variability while supporting configuration control, environmental resilience, and repeatable production across platforms and program lifecycles.

X2F manufactures patented molding machines that unlock new design freedom and support new and complex applications

Thermal & EMI Management

X2F machines mold thermally conductive materials and EMI shielding polymers directly around delicate electronics, reducing operating temperatures, providing environmental protection, and improving product performance.



X2F over-molded PCB

Advanced Materials

Supports a nearly unlimited number of polymers, pigment and fiber-filled polymer combinations, including Metal, Ceramic, fiber-filled, and Thermosetting polymers.



Molded part using high performance plastic

Faster Development

Reduces cycle and process times and requires much less power and floor space.

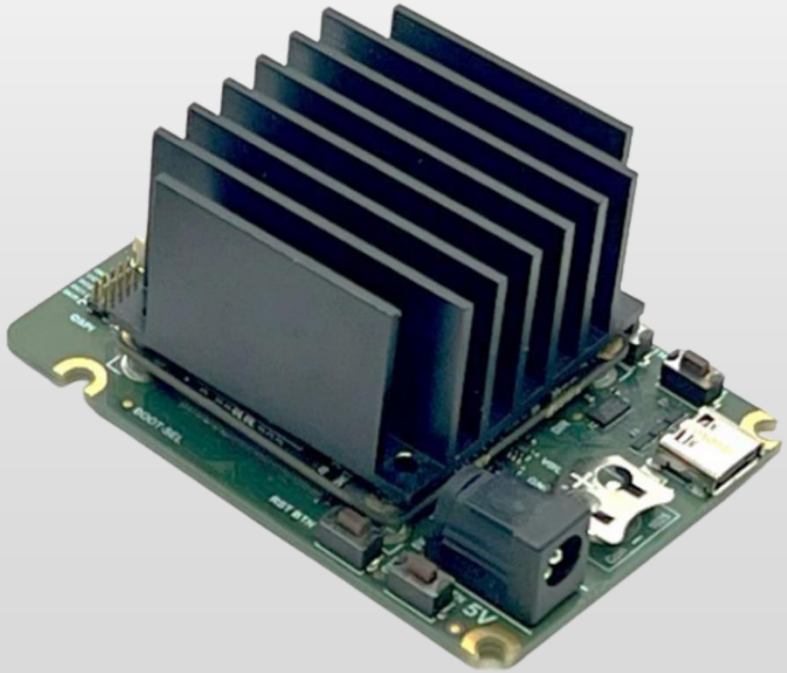


3D printed mold insert

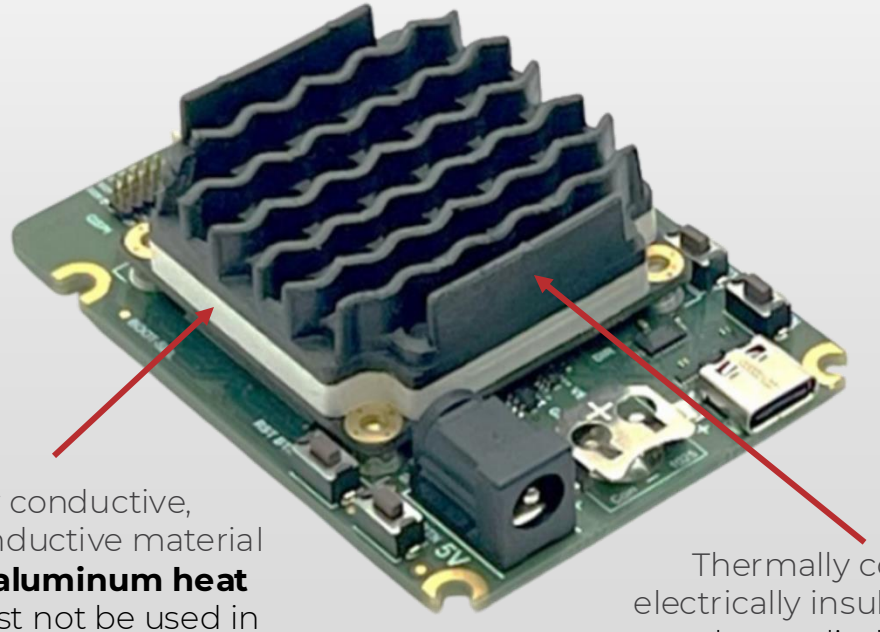
Encapsulating Electronics for Thermal Management

X2F precision molded surfaces allow **thermally conductive materials to bond directly to housings or heat sinks**, eliminating secondary interface layers. This provides **higher efficiency** in a smaller space, **fewer production steps**, and **eliminates components** and assembly cost.

Current Thermal Management



X2F Direct Molding



Thermally conductive, electrically conductive material **can replace aluminum heat sinks**, but must not be used in direct contact with circuitry.

Thermally conductive, electrically insulative material can be applied directly over circuitry where **electrical isolation** is required.

Over-Molding Electronics

Thermal Management

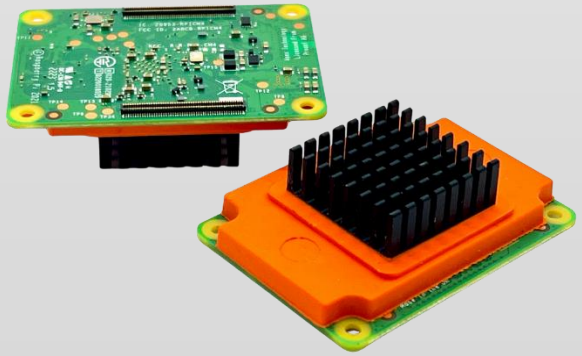
- Enables high performance passive cooling and significantly reduces operating temperatures
- Improves heat dissipation without secondary assemblies
- Eliminates the need for gap pads, thermal adhesives, and other thermal interface materials

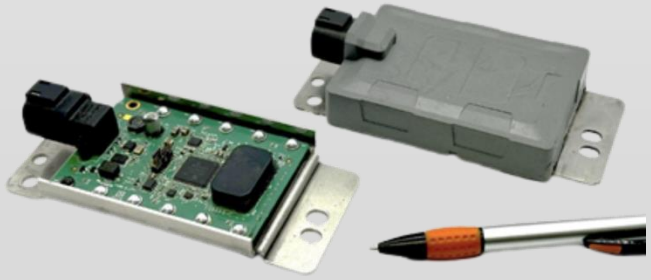
Environmental Protection

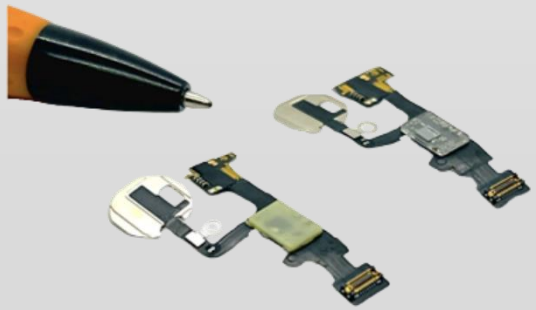
- Complete encapsulation shields electronics from moisture, chemicals, vibration, and contaminants
- Enhances durability and long-term reliability
- Advanced EMI and RFI-shielding thermoplastics improve performance and system reliability

Technology Differentiation

- Compatible with all thermoplastic families including highly filled thermally conductive polymers
- Protection and thermal management achieved with a data-driven and automated process
- Production processing cycles are reduced from many hours to minutes

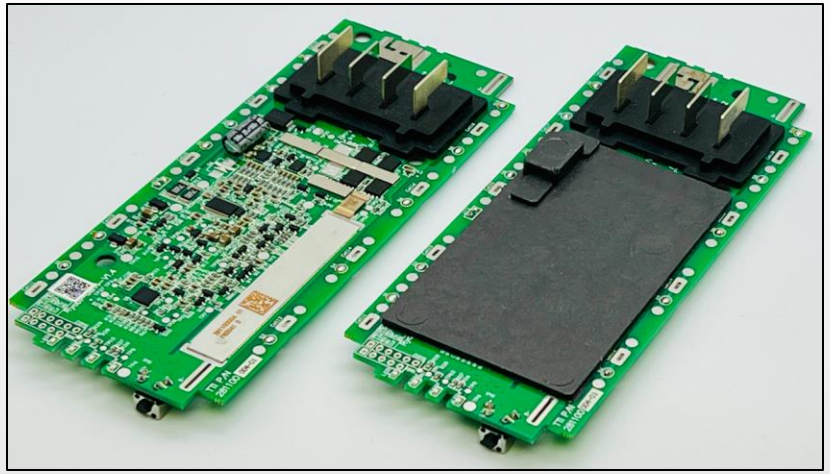






X2F Enables both Broad and Selective Encapsulation of Electronics

X2F Broad Encapsulation

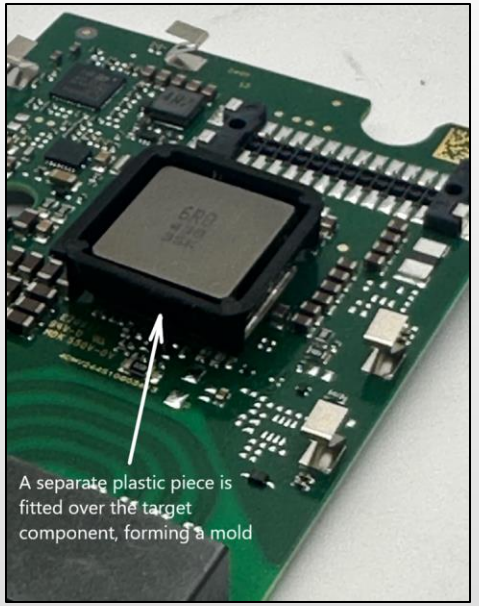


A 3” x 5” PCB and the encapsulation used to protect it.

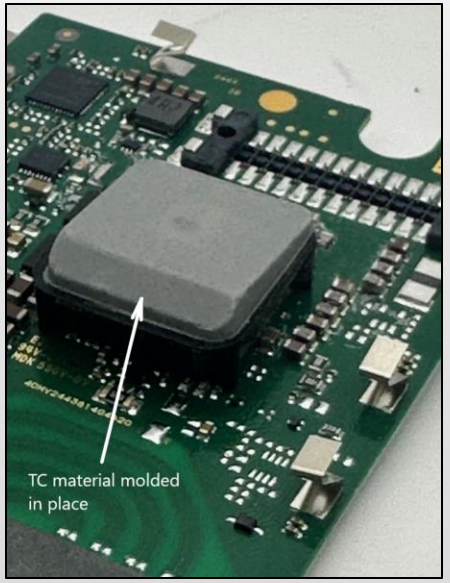


PCB component to be isolated and encapsulated

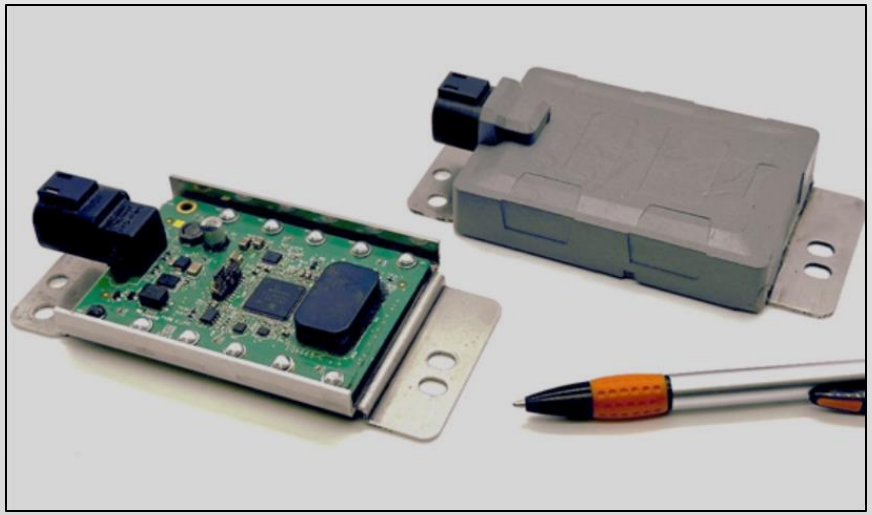
X2F Selective Encapsulation



A plastic frame is placed on the component to form a mold.



Final encapsulation with a thermally conductive material that takes heat from the component into the assembly frame.



Extreme Environments

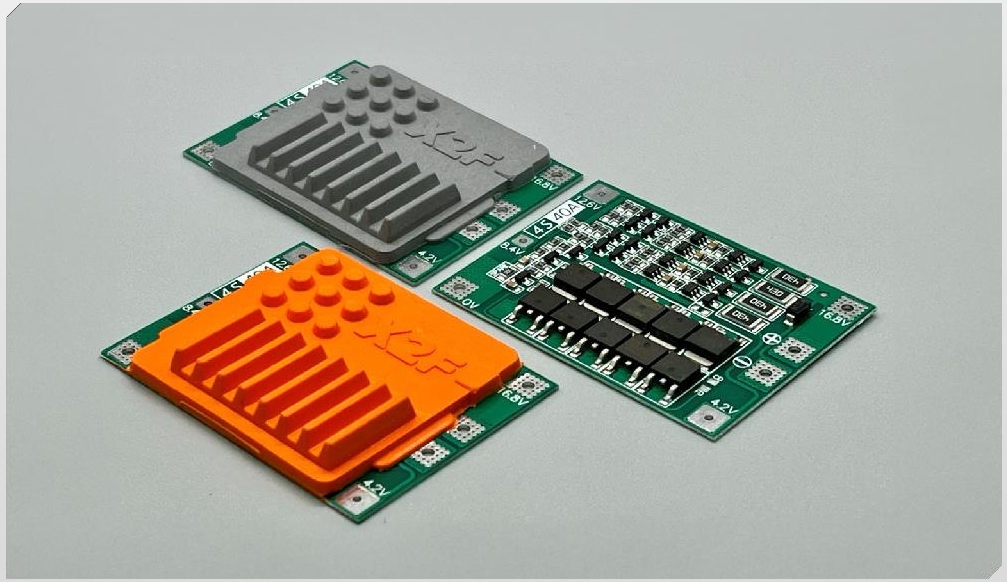
Full encapsulation of a control board for industrial excavating equipment.

Over-molding Electronics for Protection From Environment While Dissipating Heat

X2F technology **over-molds delicate electronics** with **thermally conductive materials**, **reducing component operating temperatures by 15-30%** and improving product performance and reducing cost.



Raspberry Pi single board computer

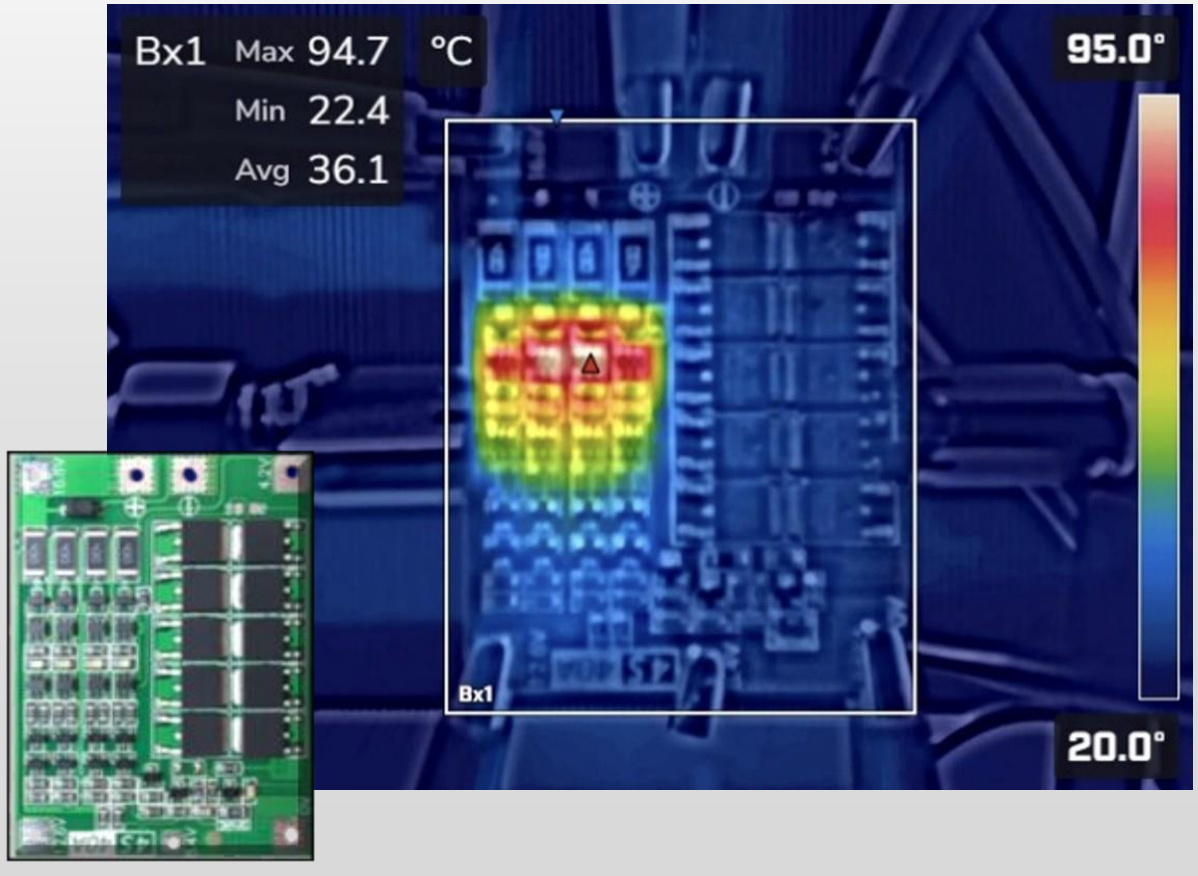


Battery management PCBs

Miniaturization and higher performance

The X2F-thermally molded PCB provides a **dramatic reduction in thermal hot spots**, enabling higher performance and durability of the PCB.

Uncoated Electronic Board



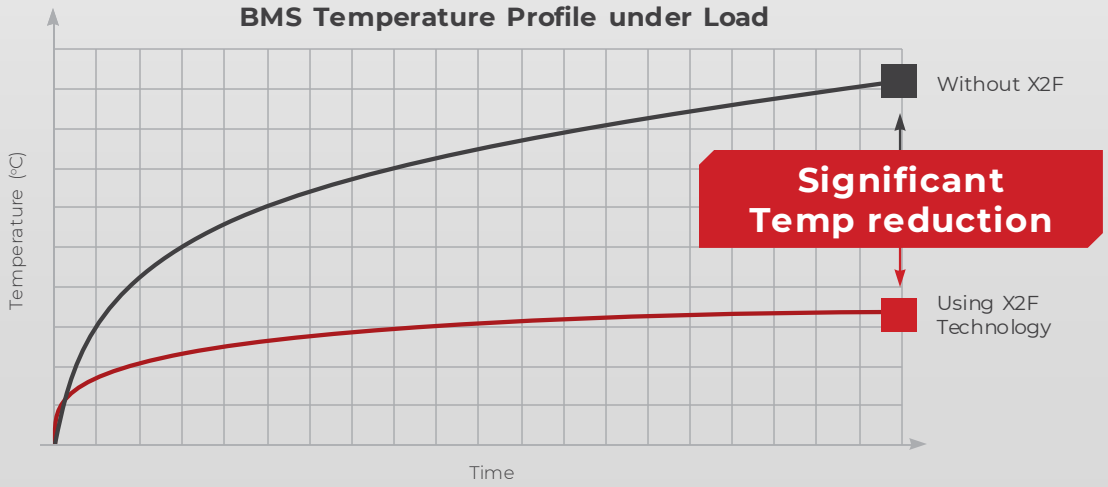
Molded with X2F Technology
(2.0 W/m.K Polyamide Material)

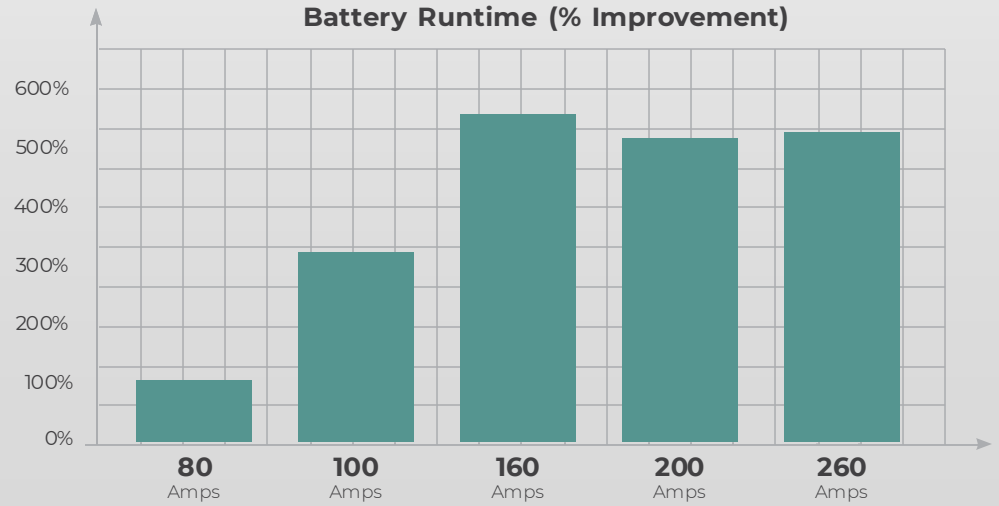


Battery Management System Thermal Molding Benefits

- **Battery performance gains**
  - Up to **500%** battery runtime improvement
  - **Faster** charge times
  - **Higher** discharge rates
- **Manufacturing improvements**
  - Highly **automated** process (vs. 50+ laborers per shift)

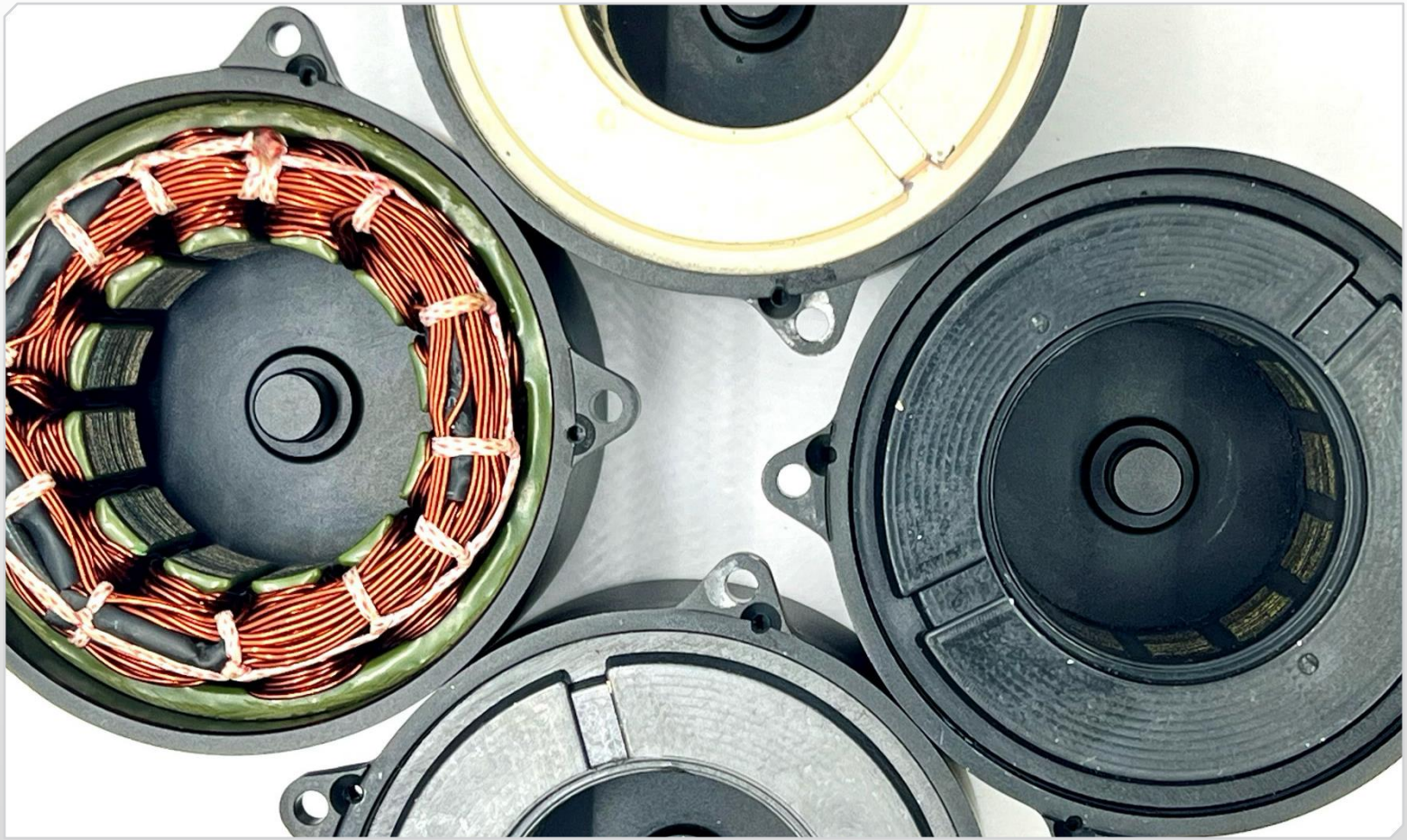






Motor Stator Encapsulation

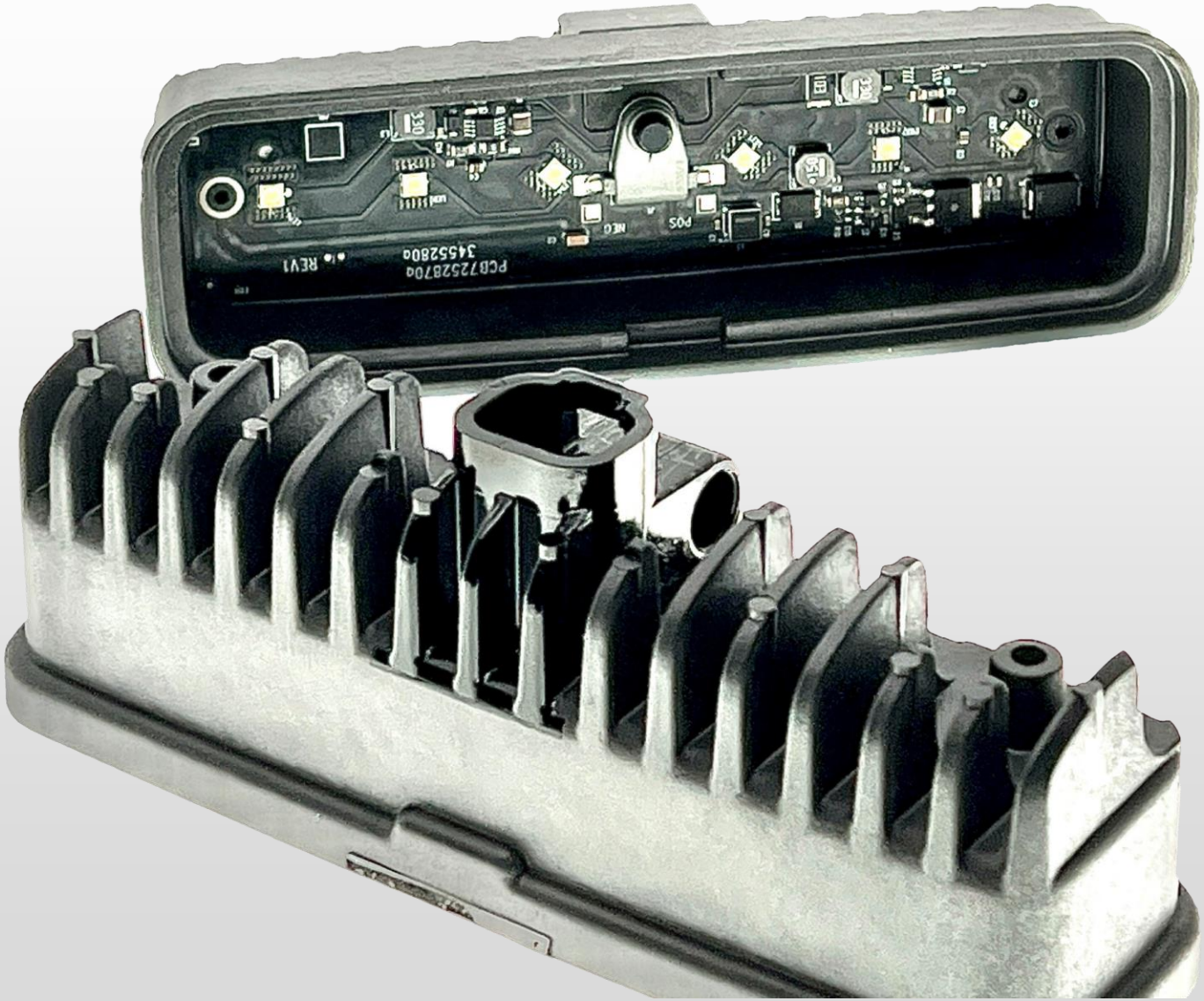
- X2F technology can encapsulate motor stator windings to create a complete and uniform **thermal transfer** solution.
- The encapsulation of the motors **reduces operating temperature**, boosts motor performance, and extends life while dramatically reducing vibration and sound.



Lighting Applications

Encapsulated PCB's with LEDs can be **molded in a single operation** with thermally conductive structural plastics

Encapsulation provides for **more effective heat transfer**, and allows for the replacement of assembled **die cast aluminum housings** with plastic that is half the weight while matching the heat transfer capability.



MATERIALS FREEDOM

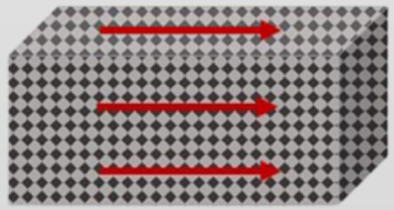
X2F Redefines High-Strength Carbon Fiber Component Manufacturing

Traditional woven carbon fiber delivers anisotropic strength that depends heavily on craftsmanship rather than a repeatable isotropic architecture. As a result, it **limits miniaturization, scalability, automation, and rapid iteration**.

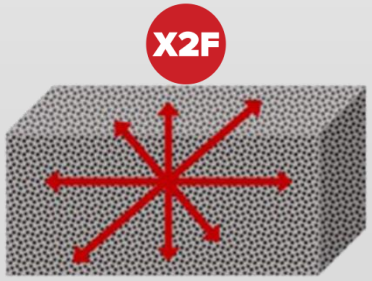
X2F Carbon Fiber Manufacturing Innovation

With X2F's process, individual carbon fibers are introduced directly into the thermoplastic during molding, allowing fibers to orient randomly in all directions.

Woven Carbon Fiber



Anisotropic layered structure



Isotropic uniform structure

The X2F Impact

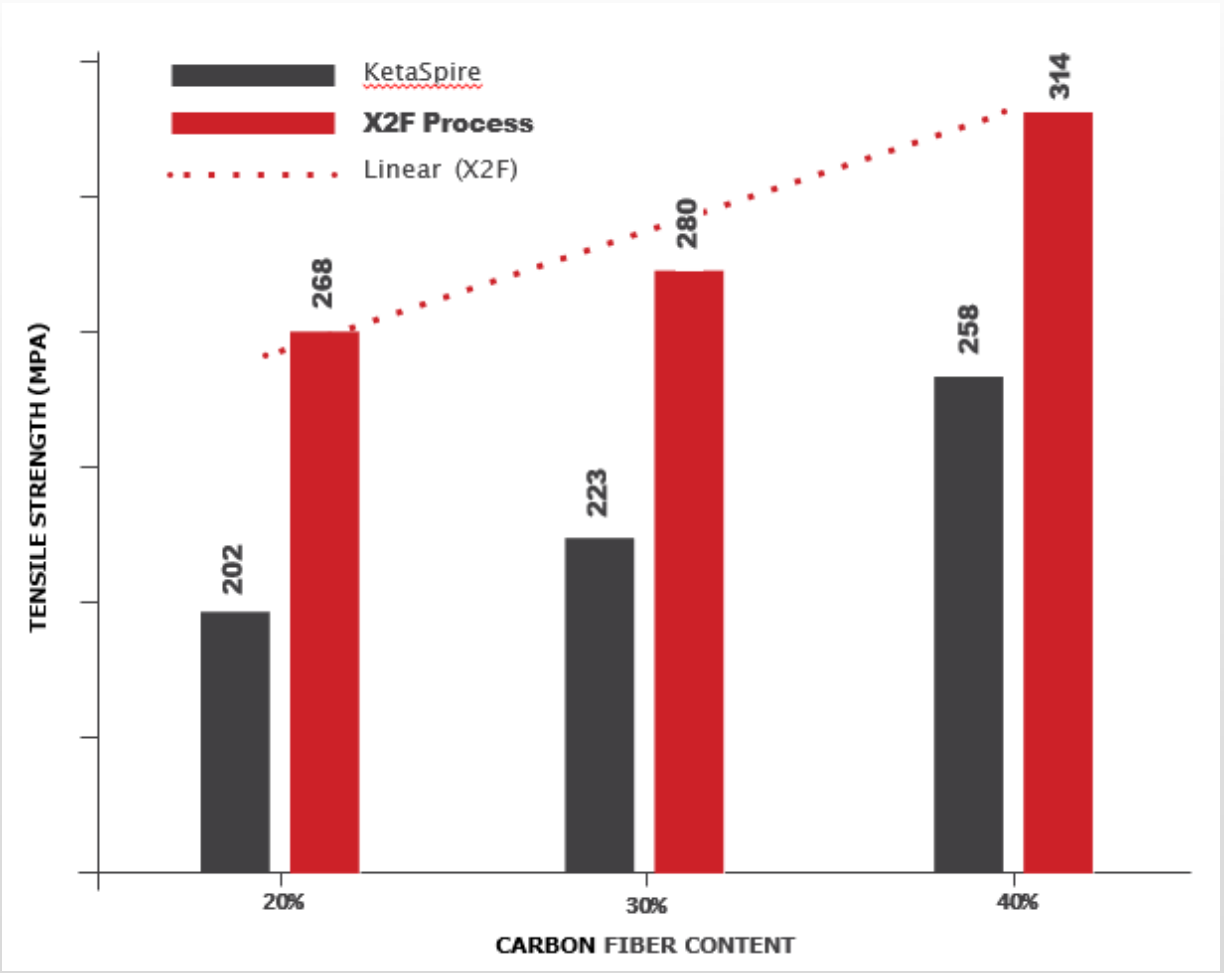
True Isotropic Mechanical Behavior
Strength is distributed in all directions, not limited to a laminate plane.

Designed for Scalable Manufacturing
Repeatable high-volume production, faster time to market, & supply chain freedom.

High Performance Plastics

By compounding at the machine, X2F's technology can build composite parts that **exceed the strength of currently available commercially scalable processes**





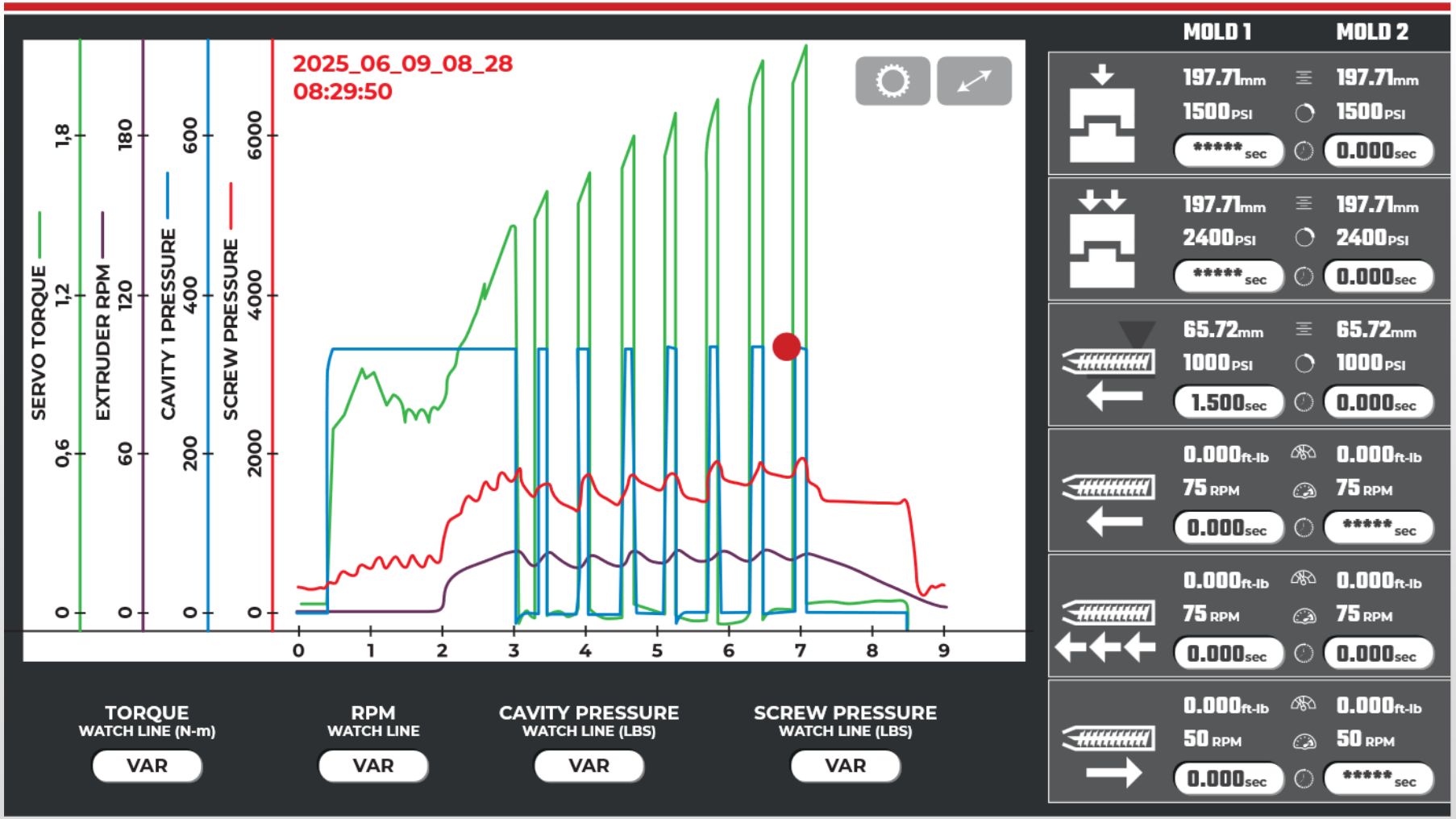
E60Vi Machine Specifications



CLAMP SECTION	UNITS	VALUE
CLAMPING FORCE	US Ton (kN)	10 (89)
CLAMPING EQUIVALENCY	US Ton (kN)	60 (534)
OPENING STROKE	inch (mm)	8.0 (203)
UPPPER PLATEN SIZE	inch (mm)	12.0 x 14.0 (305 x 356)
ROTARY PLATEN DIAMETER	inch (mm)	32 (813)
MIN. MOLD HEIGHT	inch (mm)	6.0 (152)
MAX DAYLIGHT	inch (mm)	14.0 (356)
EXTRUDER ELEVATION FROM THE TABLE	inch (mm)	4.0-10.0 (102 - 254)
EJECTION STROKE	inch (mm)	4.0 (102)
EJECTION FORCE	US Ton (kN)	1.6 (14)
MOLD LOCATION - UPPER	inch (mm)	Ø4.00 (101.6)
EJECTION CONFIGURATION		1-CENTER

MACHINE FUNCTIONS	UNITS	VALUE
EXTRUDER CAPACITY	cc/sec of PS	0-100
SYSTEM HYD PRESSURE	PSI (Bar)	2400 (165)
POWER REQUIREMENTS	Volts / Amps	360-480 - 3 Phase / 80
SERVO HY MOTOR	Kw	5
SCREW DRIVE SERVO	Kw	6.4
ROTARY TABLE SERVO	Kw	2
HEATER POWER	W	3300
NUMBER OF HEAT ZONES		8
MACHINE DIMENSIONS (L x W x H)	inch (mm)	91 x 45 x 83 (2310 x 1145 x 2110)
MACHINE WEIGHT	lbs. (kg)	2,900 (1300)
AUTOMATION INTEGRATION		Euromap 67

Machine Learning with Data-Driven Process



Screenshot of X2F **E60VI screen** during molding process showing machine parameter settings and data capture.

Analytics & Software

EDGE COMPUTE ENABLED

REMOTE MONITORING | PROCESS & MATERIAL OPTIMIZATION | DATA & INSIGHTS

Our Software Provides:

- Real-time charting of cycle data
- Cycle summary statistics
- Historical shot visualizations
- Ad-hoc reporting capability
- Local data capture at 10ms
- Encrypted Cloud Access



Figure 1: Extruder RPM and Cavity 1 pressure during operation, illustrating the direct relationship between changes in extruder RPM and variations in Cavity 1 pressure.

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Thank you!

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