MobilityScience™

Improved safety, performance, and reliability

Materials solutions for battery pack assembly

DOW®

MobilityScience™

Moving technology forward, bringing safety home

Electrification is revolutionizing human transportation and the mobility industry.

Fueled by tumbling lithium-ion battery prices, favorable government policies, and aggressive plans from automakers, the market for plug-in hybrid and battery-powered electric vehicles (xEV) is on track to grow significantly over the coming decade. But consumer demands for increased range, lifetime, and safety at ICE cost parity pose real challenges.

Our passion for low-carbon mobility drives us

Our backward integrated capabilities in materials science, research and development, and testing provide a unique skill set for the evolving challenges faced by H/EV battery producers. By combining organic, inorganic, and hybrid chemistries, we develop groundbreaking solutions that help address:

- The need for higher volumetric and specific energy density
- Increasing requirements for safe and efficient thermal management under normal operating conditions
- Solutions that help mitigate abnormal thermal or electrical events
- Ensuring battery performance throughout the expected lifetime of a vehicle
- Efficient vehicle manufacturing processes
- OEM in-house assembly EH&S standards

Adhesives, gap fillers, potting systems and encapsulants, and fire protection solutions from Dow can help battery manufacturers, automotive OEMs and designers achieve the right level of protection required for diverse battery configurations. We're happy to collaborate with you on materials' innovations and selection for your specific applications.

Enabling safety and performance: Innovative materials for battery pack assembly

Adhesives and thermally-conductive adhesives

Adhesives are used for a variety of bonding purposes. From the permanent sealing of battery-pack lids onto cases, to bonding battery cells to cooling plate, pack, or chassis structures, DOWSIL™ and VORATRON™ adhesives are available across a range of hardness, thermal conductivity, adhesive strength, and temperature resistance. Formulations can also be tailored to meet your production and application needs.

Product	Adhesive properties	Thermal conductivity*	Density (g/cc)	Durometer	Elongation (%)	Cure type	Cure time
DOWSIL™ 844 RTV Adhesive Sealant	Non-flowing moisture cure adhesive	Not relevant	1.4	37 Shore A	400	1-part	1-3 days @ 25°C
DOWSIL™ 7091 Adhesive Sealant	Excellent adhesion to many substrates	Not relevant	1.4	32 Shore A	680	1-part	3-7 days @ 25°C
DOWSIL™ TC-2035 CV Adhesive	Low temperature fast cure TC adhesive	3.3 W/mK	3	33 Shore D	50	2-part (1:1 mix ratio)	15 min @ 115°C
VORATRON™ MA 8200 Structure Adhesive Series	>8.0 MPa	<0.4 W/mk	1.3	60-70 Shore D	>80	2-part (1:1 mix ratio)	7 days @ 25°C
VORATRON™ MA 8300 TC Adhesive Series	>7.0 MPa	1.2 W/mk	1.75	60-70 Shore D	>15	2-part (1:1 mix ratio)	7 days @ 25°C

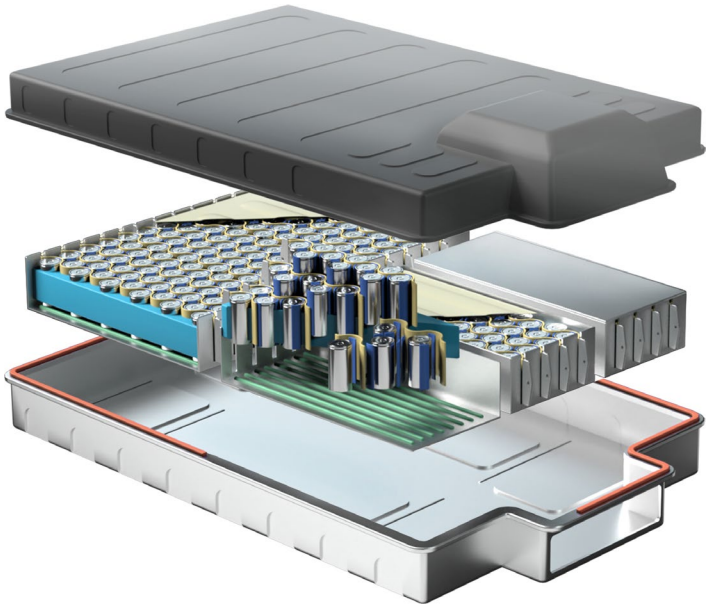
*Hot disk method

Gap fillers

Thermally-conductive gap fillers are soft, compressible, two-part, room-temperature cure materials, specifically formulated to process easily and to effectively dissipate heat from critical automotive parts —such as battery cells — and to maximize dispense equipment lifetime. DOWSIL™ and VORATRON™ thermally-conductive gap fillers exhibit shear thinning and low-squeeze force with excellent vertical hold performance.

Product	Thermal conductivity* (W/mK)	Density (g/cc)	Squeeze force (N)	Durometer (Shore OO)	Cure time (@ 25°C)	Working time (@ 25°C)	Viscosity (Pa.s @ 10 s-1)
DOWSIL™ TC-5515 LT Low Density Thermally Conductive Gap Filler	2	1.9	230	65	6 hrs	90 min	Mixed: 140
DOWSIL™ TC-5533 Gap Filler	3	2.6	80	65	24 hrs	90 min	Mixed: 40
VORATRON™ GF-1000 Series 2.0 Gap Filler	2	2.0	<120	75	Up to 7 days	>30 min	Part A and B: 50-60
VORATRON™ GF-1000 Series 3.0 Gap Filler	3	2.1	<160	75-85	Up to 7 days	>30 min	Part A: ~250-300 Part B: ~100-200

*Hot disk method



Potting resins and encapsulants

In many cylindrical cell battery designs used for H/EVs each cell needs to be surrounded by a pottant (or encapsulant) to provide isolation for individual cells and the battery during: (i) operational temperature and (ii) in case of a thermal event and to maximize mechanical stress tolerance. DOWSIL™ and VORATRON™ potting/encapsulation systems are designed to offer combinations of high strength, thermal insulation, mechanical structure to the battery pack, and most importantly (if needed) fire resistance in case of thermal runaway to the cells. These flexible to rigid, room temperature curing materials can also encapsulate only the vent caps to help slow thermal runaway propagation in lithium-ion (Li-ion) battery systems.

To ensure each cell is well encapsulated, DOWSIL™ and VORATRON™ systems have tailored rheological characteristics (ex: low viscosity) and cure kinetics (ex: open time) that enable dispensing and filling of intricate geometries and space within the cylindrical cell case. Upon dispense, the mixed materials flow and may expand, filling all gaps and preventing voids that may lead to failure in case of a runaway issue. The right elasto-mechanical properties for efficient assembly and performance help keep the cells and battery in place, while providing each cell with excellent thermal and mechanical isolation. Their lower densities produce lighter weight batteries, improving vehicle range while reducing product carbon footprint.

The Dow Foam Flow Model is a modeling and simulation tool created to enable rapid product development and iterations for simulating flow and cure of the pottants (or encapsulants). It has been validated experimentally to predict the flow, voids, densities, and max pressure in certain regions. It also enables OEMs to decide on the location of dispense, rate of dispense, and the vents for newer Dow products.

Product	Thermal conductivity (W/mK)	Cure type	Cure (time / temp)	Viscosity (cP)	Specific gravity	Durometer	Tensile strength (MPa)	Certification
DOWSIL™ 3-4150 Dielectric Gel	0.2	Room temperature or heat acclerated	1.5 hrs @ 25°C	475 (mixed)	1.0	N/A	N/A	UL 94 V-1
DOWSIL™ 3-4207 Dielectric Tough Gel	<0.2	Room temperature or heat acclerated	1.5 hrs @ 25°C	425 (mixed)	1.0	60 Shore OO	N/A	UL 94 V-1
DOWSIL™ EF-6559 Silicone Foam	Not relevant	Room temperature	10 ~ 15 min @ room temperature	10,000 (mixed)	0.4~0.5*	60 Shore OO*	N/A	
SYLGARD™ 170 Fast Cure Silicone Elastomer	0.4	Room temperature or heat acclerated	0.2 hrs @ 25°C	2,300 (mixed)	1.4	42 Shore A	3.7	UL 94 V-0
VORATRON™ 800 Series Potting Foam	<0.1	Room temperature or heat acclerated	~12 hrs @ RT for full cure	Tunable: <3,000	Tunable: 0.5-0.7	N/A	Handling strength 60 min @ 25°C	UL 94 V-0 for non-foam versions
VORATRON™ EN 2000 Potting Foam Series	<0.2	Room temperature	Tunable: 3 to 12 MPa	Tunable: <2000 cP mixed	<0.9	Shore D 30+	>20	UL 94 V-0
VORATRON™ EN 5000 Potting Foam Series	<0.06	Room temperature or heat accelerated	~8 hrs @ 75°C	< 2000 cP	Tunable: 0.2-0.4	90 Shore C	>2 MPa	Available per Request

*Density and hardness can vary accoring to foaming process

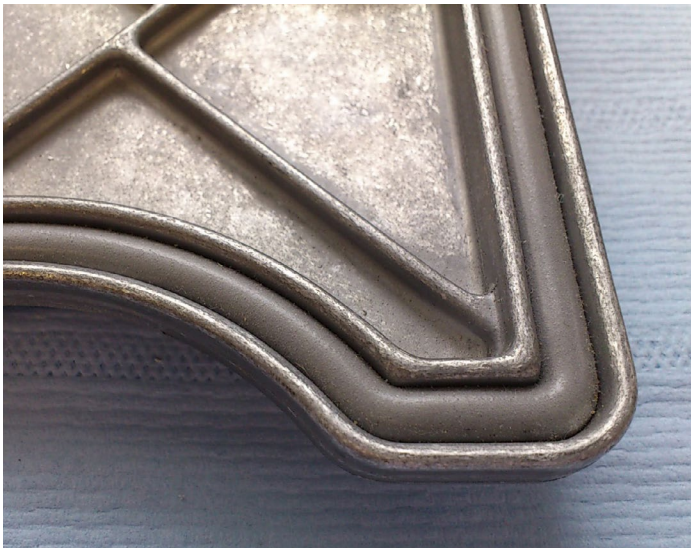
Sealing and gasketing

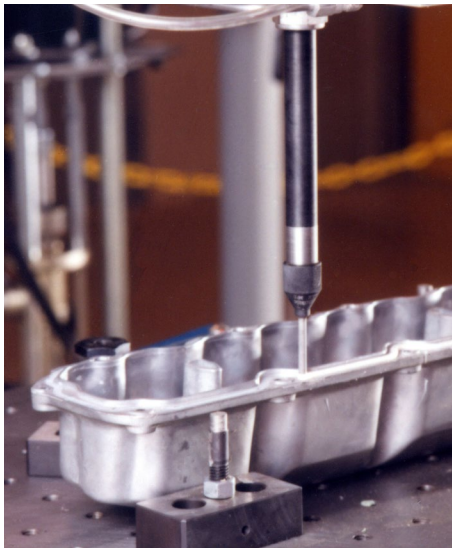
Keeping environmental elements such as moisture, salt, and dirt on the outside of the battery pack is key to battery longevity and safety but is no easy task. Sealing the housing with the appropriate materials is critical to ensuring battery lifetime and safety.

To this end, Dow has developed sealants with a wide range of properties that can be dispensed in serial production or manually. From non-porous, liquid applied cured-in-place gasket (CIPG) and formed-in-place gasket (FIPG) materials to dispensed foam gasket (DFG) formulations, DOWSIL™ sealants can be used to adhere and/or seal between a variety of substrates in an EV battery pack. These applications for EV battery can include perimeter seals for battery modules and packs, assembly adhesive for various internal components, control module sealing, etc. and offer high thermal stability and low flammability when measured **in accordance with UL standards**.

Product	Specific gravity		Viscosity (mPa s)		Snap time (minutes)	Cured density (g/cm³)	Durometer (Shore OO)
	Part A	Part B	Part A	Part B			
SILASTIC™ 3-8186 Thixotropic Foam	1.1	1.2	135,000	125,000	3.5	0.2	35
DOWSIL™ 3-8259 RF Silicone Foam	1.1	1.0	68,000	63,000	2.5-3.7	0.3-0.4	50
DOWSIL™ 3-8257 Silicone Foam	1.1	1.0	21,000	12,000	2.5-5.0	0.1-0.2	25

Product	Specific gravity	Tack-free time (min)	Durometer (Shore A)	Tensile strength (MPa)	Elongation (%)
DOWSIL™ 7091 Adhesive Sealant	1.4	28	32	2.5	680
DOWSIL™ 844 RTV Adhesive Sealant	1.4	25	37	2.2	400



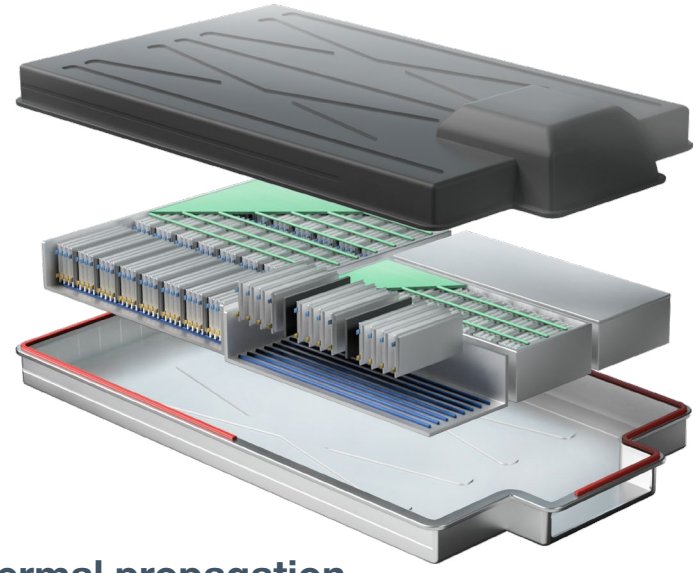


Battery lid and tray structures

Battery lids and tray structures are important mechanical, thermal, and safety components of a battery pack. They help manage the temperature of the cells to ensure thermal uniformity and controllability across a range of environmental conditions, while delivering stiffness and mechanical strength to the battery pack and vehicle. In the case of an abnormal event, the pack enclosure and lid are a critical layer of protection between hot, flammable gasses and metals, and vehicle occupants. For decades polyurethane foams have been used in sandwich-panel construction, and battery packs are no exception. Our VORATRON™ foam systems can be used at several steps in battery pack production to efficiently assemble lid or tray structures, providing the necessary stiffness, thermal insulation, and safety benefits.

VORATRON™ EP 3000 Assembly Foam Series of high-strength and density foams was particularly designed to develop adhesion between the different e-coated metal panels or pre-treated plastic composite plates. The high strength of foam (stiff and tough) enables assembly of layers of the pack to behave as one component. The ease of application and tailored open time ensure complete fill of narrow gaps (1-10 mm) and closed cell structure enable thermal insulation.

VORATRON™ EP 3000 Assembly Foam Series	
Adhesion strength (on e-coated metal)	> 5 MPa with cohesive failure
Thermal conductivity	< 0.1 W/m.K
Cure temperature	30-50°C
Open time before foam rise	1-3 minutes
Final hardness	20+ Shore D



DOWSIL™ foams for prevention of thermal propagation

Dow offers a range of liquid silicone foam products that can be converted into foam sheets — solutions that meet your application needs. Combining thermal insulation with compressibility, DOWSIL™ silicone foams are two-part systems cured into elastomeric foams in a platinum-catalyzed, polyaddition reaction, with a range of densities and mechanical properties. These silicone foams can be cured in a wide range of temperatures — from room-temperature up to > 100°C to account for the varying processing requirements in battery fire protection.

DOWSIL™ foams can be used to produce sheets that provide a variety of benefits in an EV battery pack. These sheets can be easily placed or adhered between battery cells, battery modules, or in other areas of the battery pack. These low-density materials can act as a compression pad, providing needed compressive force to improve battery performance, or maintain pack structural requirements. They also have excellent thermal insulation, mitigating thermal runaway propagation.

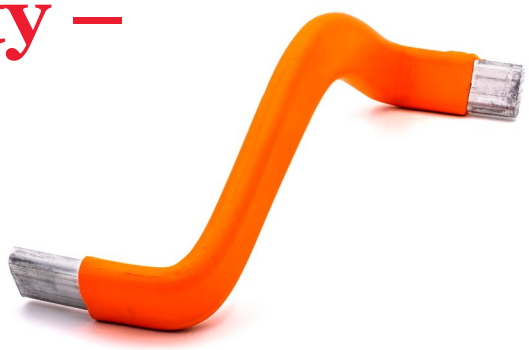
Product	Viscosity (mPa s)		Snap time (min)	Density (g/cm³)	Recommended cure temperature	Durometer (Shore OO)
	Part A	Part B				
DOWSIL™ 3-8209 Silicone Foam	14,000	15,000	4	0.25	RT	45
DOWSIL™ 3-8235 Silicone Foam	77,000	91,000	3	0.21	RT to 100°C	35

DOWSIL™ EF-6500 Series Silicone Foams specifically formulated for battery fire protection

Product can be tailored to meet your application needs. Customized solutions available with improved battery fire protection performance.

Product	Viscosity (mPa s)		Snap time (min)	Density (g/cm³)	Recommended cure temperature	Durometer (Shore OO)
	Part A	Part B				
DOWSIL™ EF-6555 Silicone Foam	28,000	31,000	13	0.24	30 min @ RT, can be accelerated by heat	38

Performance and safety – when the heat is on



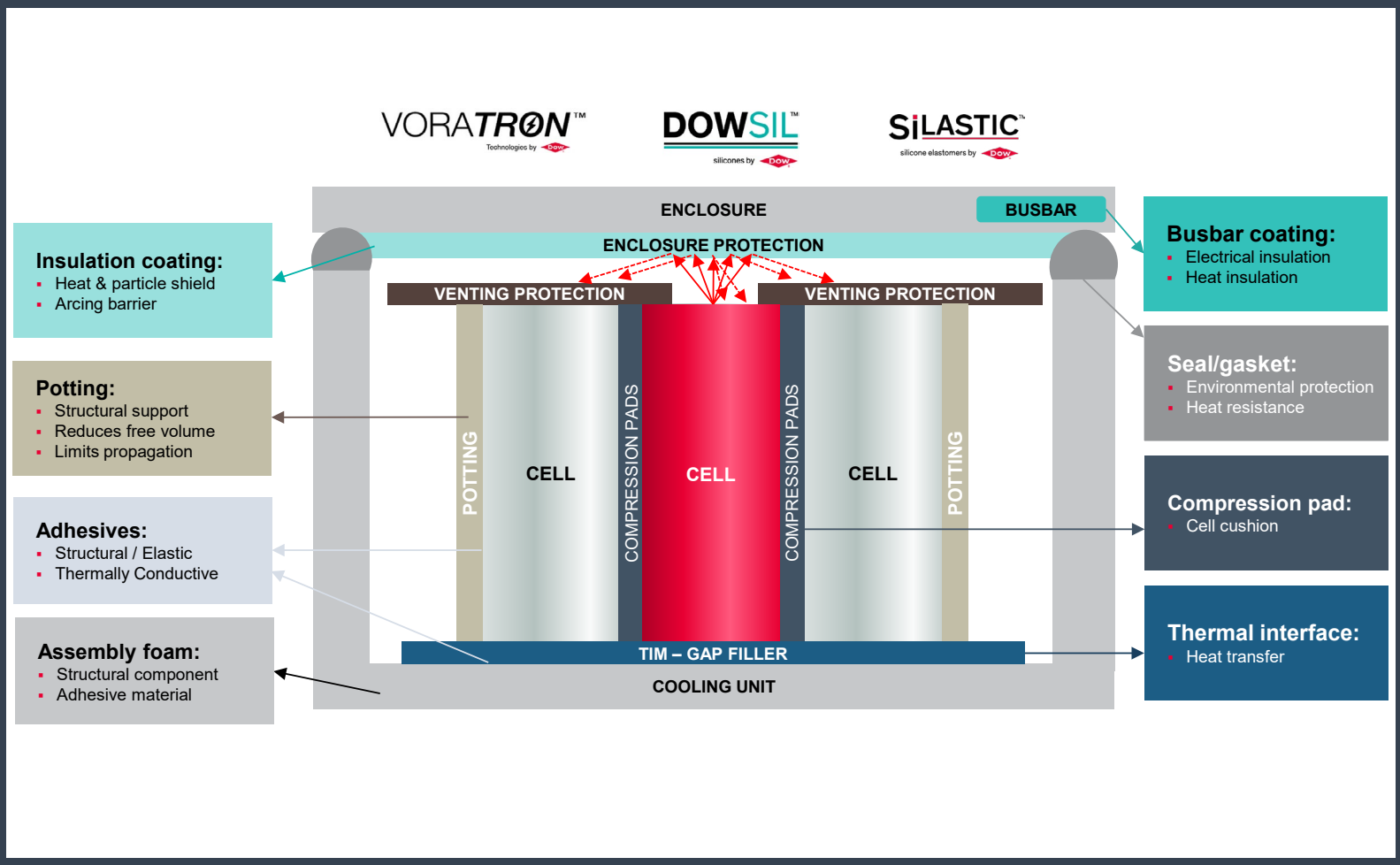
Protective electrical and thermal insulation for busbars, hoses, and barrier applications

Elastomeric, SILASTIC™ high-consistency rubbers (HCRs) have been used for decades to provide long lasting electrical insulation in High Voltage electrical distribution and transmission applications, and in production of safety cables, ensuring operation of critical safety systems during a fire. Electrical vehicle battery packs share similar requirements to these applications. Dow has developed several grades of extrudable, calenderable, and moldable HCRs that are flame resistant —or ceramify — to form an electrically and thermally-insulating, inorganic layer when exposed to flame or high temperatures. These formulations are designed specifically to protect high-voltage conductors and cooling tubes. Additionally, a spray-applied coating is available on request for applications such as a battery lid thermal barrier.

Dow offers an extensive portfolio of battery fire protection materials. Ask your technical service representative for more information.

	FLAME RESISTANT		CERAMIFYING		
Application	**Vent seal / Valve**	**Thermal barrier / connection cover**	**Busbar coating**	**Hose protection**	**Connection cover**
Need	Thermal seal / valve	Thermal barrier	Thermal / electric insulation	Thermal insulation	Thermal / dielectric insulation
Product recommendation (HCR - High consistency rubber)	**SILASTIC™ HCM 50-1339 FR RED**	**SILASTIC™ HCC 67-1347 FR RED**	**SILASTIC™ HCx 67-1352 EV FR ORG**	**SILASTIC™ HCE 60-1335 FR RED**	**SILASTIC™ HCC 65-1351 EV FR RED**
Use form (Fabrication)	Injection, transfer, and compression moldable	Calender and compression moldable	Extrudable or injection, transfer, and compression moldable	HAV, IR, Salt bath, extrudable	Calender and extrudable
Product details	• 50 Shore A • Good thermal and flame resistance • Tested to UL 94 V-0, 4.0 mm	• 67 Shore A • Robust mechanical properties • Good thermal and flame resistance • FMVSS302, 2.0 mm • Tested to UL 94 HB at 2.0 mm	• 65 Shore A • Improved fabrication performance • Flame resistance • Forms ceramifiable layer • Color RAL 2003 (safety orange)	• 60 Shore A • Flame resistance • Forms ceramifiable layer	• 70 Shore A • Flame resistance • Forms ceramifiable layer

MobilityScience™



Dow builds on 100+ years of transportation experience and expertise in application development to deliver innovative, cutting-edge solutions that keep the world moving. Our MobilityScience™ team provides OEMs and tiers with a seamless and collaborative global partner for materials innovation, through access to world-class technical capabilities, and a broad portfolio of materials science solutions for the industry. Dow is committed to the future of mobility and is addressing the most pressing mobility challenges like de-carbonization and improving EV performance.

Whether your application requires high strength, high-temperature performance — or both, our expertise in chemistry and formulations coupled with skilled and knowledgeable technical service can help you improve performance, safety, cost, and sustainability.

We're enabling battery manufacturers to take on the heat with confidence.

MobilityScience™

How can we help with your latest innovations?

Learn more at **dow.com/battery** and **dow.com/mobilityscience**

Images: 168193865, 76561137389, 460606725, 74670295846, 74670295846, 40644846737, 40145739955, 40145820185, 74670169258, 569079787, 596327411

2000030982-69550

Form No. 80-8632-01-0325 S2D