

ENCAPSULATION AGENT SOLUTIONS FOR LITHIUM ION BATTERY & MIXED FUEL FIRES

EV-EXBOX



Technical Briefing Paper - Encapsulator Solutions for Lithium-Ion battery Fires

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Rethinking Fires

Modern automobiles with ethanol-blended fuels, magnesium, titanium and aluminium components, plastic trim parts and tyres are challenging enough, but with more and more hybrid and electric vehicles on the road with high-voltage lithium-ion batteries, car fires have become more than a challenge.

An electric vehicle is not just a lithium-ion battery that has to be extinguished - the vehicle must be considered as an entire component.

A modern-day vehicle fire and particularly an EV or hybrid car cover almost every fire category there is.

In most instances large volumes of water are recommended as an extinguishing agent for EV fires. However, you need a lot more water to extinguish an EV / Hybrid vehicle compared to conventionally powered vehicles. This large amount of water plays a major role in the logistics of storing extinguishing water and later disposing of the contaminated extinguishing water or preventing it from contaminating the environment.

Therefore, we believe that in order to effectively tackle an EV fire it is more effective to use a product that can cover multiple classes of fires.

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Encapsulation Agent

After undertaking several product reviews and through talking to emergency response services it appeared that encapsulation agents provided the best means of tackling both lithium ion and multi component fires.

We believe the key criteria for an effective modern firefighting product should include the follows:

- Effective against lithium-ion battery fires
- Effective against multi component fires
- Rapid cooling
- Encapsulates Fuel (where present)
- Interrupts free radical chain reactions
- Reduced volume of water for fire fighting
- Reduce smoke / airborne particulates
- Must not contain PFA / PFOS
- Must be readily biodegradable
- Simple to use with current firefighting equipment
- Have a long shelf storage life

The Encapsulator Agent GW Environmental have sourced meets all of the aforementioned attributes. It is manufactured in the USA, but we import it into Europe and the UK. It is not a foam, so it contains no fluorinated ingredients, such as perfluorooctyl sulfonate (PFOS).

It meets all U.S regulations regarding its 100% biodegradability and is non-hazardous, containing no ingredients reportable under the Superfund Amendments and Re-authorization Act (SARA) Title III, Section 313 or the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Shelf life is 15 years, and it can be discarded as a non-hazardous waste under RCRA CFR261.

As stated, this is not a foam but an encapsulation agent that is missed with water between 2% - 3%.

What Is Encapsulation & How Does It Work?

The Encapsulation Agents forms a protective skin around the water droplets which reduces the formation of steam and helps promote a rapid reduction the temperature of a fire through the encapsulation agent's ability to absorb heat energy 6-10 times greater than plain water.

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The Encapsulation Agent forms Spherical Micelles or “chemical cocoons” that encapsulates fuels rendering them non-flammable and non-ignitable.

It then interrupts the free radical chain reaction of the fire tetrahedron. This interruption results in reduced smoke and soot and most importantly a drastic reduction in airborne toxins.

The Encapsulation Agent is able to form and maintain stable spherical micelles capable of encapsulating combustible and flammable liquids (nonpolar and polar), rendering the flammable liquids non-flammables, nonignitable and nonexplosive and maintain that encapsulation in the presence of high heat over an extended period of time.

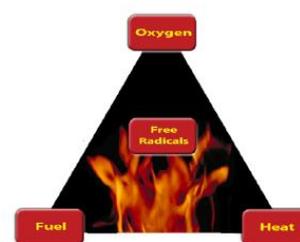
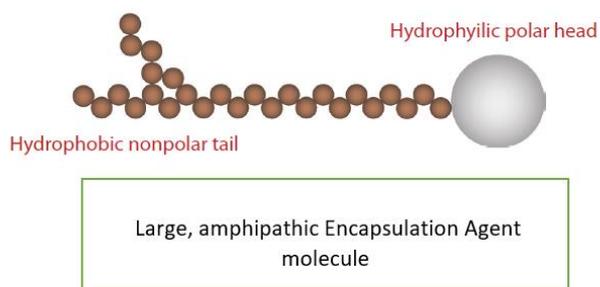
The Encapsulator Agent work on all four legs of the Fire Tetrahedron at once, removing the heat, neutralizing the fuel by separating it from the oxygen on a chemical molecular level and interrupting the free radical chain reaction. In the case of lithium-ion batteries its ability to rapidly cools stops thermal runaway far quicker than water.

In addition, flammable and toxic electrolyte released during a lithium-ion battery can increase with the use of plain water. **Encapsulation** can render this electrolyte non-flammable.

These unique properties make Encapsulator Agent a versatile firefighting agent. Unlike foam which must form and maintain a perfect blanket to separate the fire from the oxygen, Encapsulation Agent Spherical Micelle technology encapsulates the fuel and vapours on a molecular level rendering them non-flammable. This is very important for three-dimensional fires including Class A, Class B (polar and nonpolar), Class K, Class D and Lithium-ion Battery fires.

The Encapsulation Agent immediately reduces the surface tension of the water. This makes the water droplets smaller creating more surface area to absorb heat and better penetrate into the pores of solid fuels.

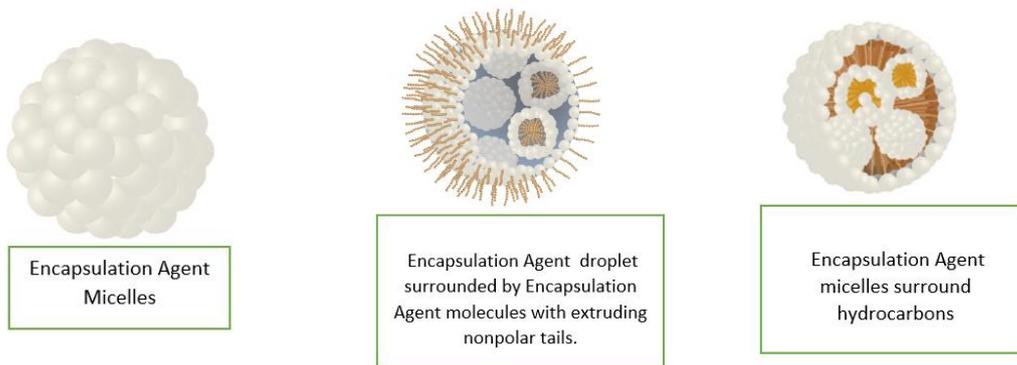
The Encapsulation Agent is a large amphipathic molecule, meaning it has a hydrophilic polar head and a hydrophobic nonpolar tail that act independently. When mixed with water, Encapsulation Agent molecules form spheres, or micelles, as the nonpolar tails try to get away from the water.



Fire Tetrahedron

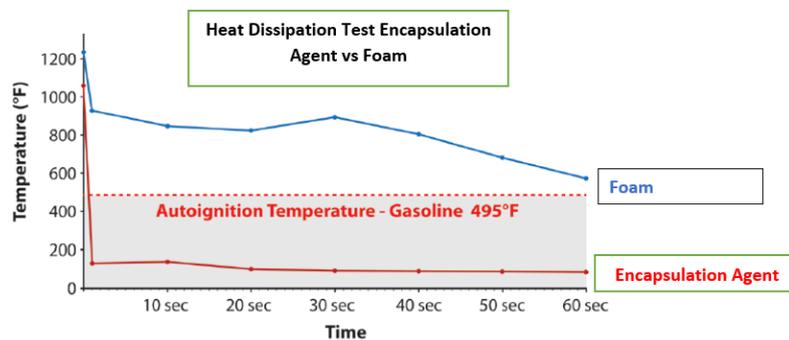
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As these micelles leave the nozzle, the nonpolar tails nearest the surface turn outward, forming a protective skin around the Encapsulation Agent droplet. There will be many micelles within the Encapsulation Agent droplets. The Encapsulation Agent tails have an affinity for hydrocarbons and attach themselves to the fuel, whether it is liquid or vapor. The nonpolar tails turn inward toward the hydrocarbon forming micelles or chemical cocoons around the hydrocarbon molecules. The hydrocarbon is now non-flammable.



Plain water droplets convert to steam as they heat up, but Encapsulation Agent droplets are surrounded by Encapsulation Agent molecules, and they therefore efficiently absorb the heat by Thermal Conveyance. In fact, tests show these droplets remove 6-20 times more heat than plain water droplets.

The cooling of the fuel, battery or solid structures is rapid. The (following) chart shows the testing of two steel plates heated to 1200°F. Within seconds, the Encapsulation Agent reduced the temperature to 127°F. The problem with foam is it traps in the heat which remains above the autoignition temperature of the fuel throughout the test. To the same effect it will not slow down or stop thermal runaway.



Clemson University heat dissipation test

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The Encapsulation Agent reduces the surface tension of the water increasing the penetration into the fuel. It reduces the temperature, preventing burn back, and encapsulates the fuel rendering it non-flammable. The final step is the interruption of the free radical chain reaction. This reduces smoke and soot, greatly reducing toxins, including cancer-causing toxins and improving visibility for firefighters.

History of Encapsulation Agents

The most common question we hear is why have I not heard about this before? The question is quite simple.

The need for a firefighting medium for lithium-ion battery fires is relatively new. The Encapsulation Agent was already being used for all other fire classes in the U.S and now it can tackle lithium ion.

The Encapsulation Agent has been available in small handheld fire extinguishers for a long time for electrical fires in confined spaces, it is used by both the Italian and Dutch navy on board their ships.

The challenge of the EV / Hybrid is the battery sizes and latent energy stored within them has meant that a handheld fire extinguisher solution is simply not viable in terms of its effectiveness or safety.

At present PFA / PFOS foams have been relatively cheap - although they present their own environmental hazards and are not suitable for lithium-ion battery fires. New non PFA / PFOS will come onto the market but will be much more expensive than their predecessors.

The encapsulation agent now needs to be deployed in a way that supports emergency services either through its direct purchasing by local authorities or by the provision of EV charging or lithium-ion handling facilities for the use of emergency services in attendance to these fires.

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2009, March	Bosch undertakes fire testing of water, foam, powder and Encapsulation Agent on lithium-ion and nickel-metal hydride batteries, as well as other production parts.
2009, March	Encapsulation Agent was chosen as a product of choice by Bosch for extinguishing lithium-ion batteries
2009, July	Bosch communicates their findings at VDA (Verband der Automobile Industrie). The VDA association nationally and internationally promotes the interests of the German automotive industry.
2010, August	Bosch share their internal test report with the Baden-Wurttemberg State Fire School.
2011, January	Shortly after receiving the test results from Bosch, Baden-Wurttemberg Fire School publishes an Application Guideline on the Potential Dangers Involving Vehicles with Lithium-ion Batteries on their website. The Application Guideline specifically references the use of Encapsulator Agent to mitigate this hazard.
2012, October	DEKRA issues a press release announcing their testing of products for Lithium-ion battery fires and releases their final report commending the Encapsulation Agent
2013, March	Hockenheim Circuit test and accept the Encapsulation Agent as their only firefighting agent, replacing all foam.
2013, April	DEKRA Automotive GmbH, Daimler AG, and Deutsche Automotive GmbH & Co. KG present the DEKRA Report findings in Detroit, MI at the SAE International Conference. The report receives much attention from NFPA and the US Automotive Industry.
2016, January	General Motors specifies Encapsulator Agent for GM's Lithium-ion Battery Abuse Lab. USA
2016, January	Tesla specifies Encapsulation Agent for battery charging area USA
2016, January	Jaguar UK undertakes Encapsulation Agent testing on lithium-ion batteries at Jaguar's facility.
2016, February	Jaguar standardizes on Encapsulation Agent for lithium-ion battery protection.
2016, July	In cooperation with the Energy Research Centre of Lower Saxony (EFZN) Goslar, rigorous month-long fire behaviour tests were conducted on various types of lithium-ion batteries to address the spread of fire, temperature measurement, air emissions, and sewage water analysis with and without extinguishing the burning batteries. The Encapsulation Agent proved to be exceptionally effective.
2017, July	The independent Dutch certification body KIWA, which oversees the testing and certification of extinguishing devices, tested and evaluated the Encapsulation Agent alongside common extinguishing agents such as powder and foam. Tests (KIWA no. 16120045) concluded that, of the tested agents, when used properly, only the Encapsulation Agent was able to extinguish the burning lithium-ion batteries and reliably stop the spread of fire caused by thermal runaways before the cells exploded. The battery did not re-ignite in any test after suppression.

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Testimonial Nr. 14pm19 / N4.40.2.2 Press Office January 27, 2014, District Office of Böblingen, Germany

"A New Extinguishing Agent Has Been Implemented in the District of Böblingen. A Special Extinguishing Agent Which Extinguishes Faster and Better. Böblingen is the first in Baden-Württemberg to use the Encapsulation Agent district wide. A powerful fire brigade is essential in every city and town. They must be well equipped to handle emergencies".

The new extinguishing Encapsulation Agent has been used extensively throughout BadenWürttemberg district, and now is being used exclusively on fire engines in Böblingen. The agent extinguishes fires faster and better and is more environmentally friendly. "We have in the district of Böblingen a network of highly effective stores of the Encapsulation Agent in small quantities with larger quantities available for major events," says Vice-District Wolf Eisenmann.

The operational concept functions in two stages. Between 20 and 400 litres of the Encapsulation Agent is available in the cities and communities for smaller fires. In the cities of Herrenberg and Böblingen are two roll-off containers with 4,000 litres of Encapsulation Agent. If there is a large loss event, a container is delivered to the scene of the fire where it can be connected to eight fire engines.

The preplanning by the district is clearly evident. "Not every community needs large amounts of the Encapsulation Agent, but we want everyone to be well equipped for any future firefighting events," said Eisenmann. The two roll-off containers are also available to other counties in the state. The district of Böblingen has invested 60,000 euros in the installation of the two containers. "All the fire trucks in the district of Böblingen can use the new Encapsulation Agent without any modifications.

The Encapsulation Agent is added to the water tank to produce the desired ratio. Experience has shown a 2% - 3% mixture to be successful on Class A fires. As usual, it is applied to a fire with a standard firefighting nozzle," said District Fire Chief Guido Plischek. Throughout the region, approximately 7,000 litres of Encapsulation Agent are available. Moreover, in Leonberg, 500 litres of it are stationed for use in case of fire in the Engelberg tunnel.

District Fire Chief Plischek reported that last year they experienced two major fires where the Encapsulation Agent was used. In both cases, the intensity of the fire was greatly reduced and there was a rapid cooling in the area around the fire. The Encapsulation Agent is also particularly well suited for electric vehicle fires. "All in all, the product has exceeded our expectations with very positive results."

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Tunnel - Extinguishing tests with Encapsulation Agent at the IFA Balsthal training center in Switzerland

The extinguishing tests were carried out in such a way that the structural cooling of the tunnel was carried out first. After ten minutes of pre-burning, the ceiling temperature was measured at 350 degrees Celsius.

After 40 seconds of Encapsulation Agent application to suppress the fire, the temperature decreased to 80 degrees Celsius and after 2 minutes to 50 degrees Celsius. There was no increase in temperature after that.

During the trials the HF gas levels from the burning lithium-ion battery were recorded at 2,656 PPM. With the application of the Encapsulation Agent the HF gas levels dropped to 37.45 PPM which is under the NIOSH's 10-minute exposure limit of 95 PPM."

Commercial Benefits of Encapsulation Agent

The ability of the Encapsulation Agent to handle almost any fire is the main reason firefighters should carry it or it should be made available for firefighters to use on site. The Encapsulation Agent has amazingly fast knockdown capabilities and interrupting the free radical chain reaction means reduced toxic smoke and better visibility for firefighters, especially in confined spaces such as tunnels or carparks. Also, since it doesn't evaporate into superheated steam, there are fewer reported burns from steam.

For example:

A fire department could be called to a car accident with spilt fuel between a normal car and an EV. The Encapsulation Agent can very quickly extinguish the fire and encapsulates the fuel spill.

If we assumed 100 litres of fuel had been spilled onto the road this is likely to cover an area of 200m². To completely encapsulate the spill, 5 litres of Encapsulation Agent would be needed when mixed with water

The firefighter would set the eductor to 3% and encapsulate the spill in about 30 seconds with an 80-gpm nozzle and hand line.

In contrast, the foam will need to be applied for 15 minutes, per the NFPA foam standard. At 3%, using an 80-gpm nozzle, 1,200 gallons of water will be applied and 130 litres of AFFF foam.

If the foam blanket breaks down while the gasoline temperature is still high, additional foam will need to be applied. The spill would more than likely be an ethanol-blended fuel, such as E10, in which case, a more expensive AR-AFFF foam would have been required

When comparing the encapsulation Agent to foam it is always good to not compare the like-to-like litre cost but how much of the Encapsulation Agent you would actually need to use vs the total amount of foam required.

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In the instance of an EV non-EV car collision resulting in a fire would a fire department use AFFF or AR-AFFF? There would be multiple hazards in this accident; Class A materials, Class B polar fuels, Class B nonpolar fuels, Class C high-voltage lithium-ion batteries, Class D combustible metals and of course, three-dimensional firefighting.

The use of the Encapsulation Agent gives a single product solution, that uses less water.

This means not only is the product not harming the environment as it is PFA / PFOS free in fighting a fire with the Encapsulation Agent less contaminated fire water is created.

Our Goal

At GW Environmental we want to help fire fighters tackle fires more effectively and we believe the clean energy transition has overlooked many risks associated with Lithium-ion batteries in cars, scooters, e – bikes and even in their recycling.

We want to provide a product that the fire services are happy to have as an option at their disposal for tackling EV / Lithium-ion battery fires.

We believe any additional costs for procuring the Encapsulation Agent should not be carried by the Fire Authorities or the Taxpayer.

We believe companies that have invested in installing EV charging points or have on site battery storage have a responsibility to ensure appropriate fire fighting materials are on hand to use.

This is why we are approaching the Oil majors, EV charge post operators and EV vehicle manufacturers to install our EV-EXBOX in strategic locations on their premises. Each box would contain up to 100 litres of concentrated Encapsulation Agent that could convert to between 3500 - 4000 litres of highly effective firefighting liquid when mixed with water. A liquid that absorbs =20 times the heat of water alone.

Building an EV Risk Concious Network

In addition we are trying to create an internation community with regards to how lithium – ion battery fires are tackled. At GW Environmental we have now estbalished strong links with the UK National Fire Chiefs Council and Fire Authorities across the U.S.A and Australia.

We are always looking to share best practise and openly invite our colleagues to demonsttrations and trials of the product where we feel there is a wider ebenfit to the safety of fire fighters, the Public and the Environment.

The EV-EXBOX Soloution will be launched in January 2023 we hope it is adopted by private businesses and corporations to help make fire fighting more effective and safer for everyone.

EV-EXBOX is a trading name of GW Environmental & Consulting Ltd. Company Registration 11968361
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Thankyou for taking time to read this paper. If you have any questions please do not hesitate to contact Graeme Warnell by email at Info@gwenvironmentalconsulting.com or by phone on +44 7766 107088