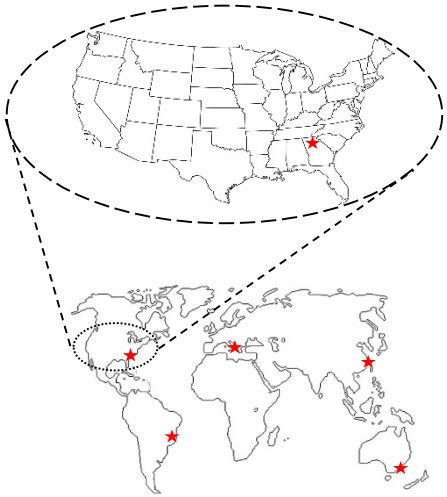
Hazard Control Technologies

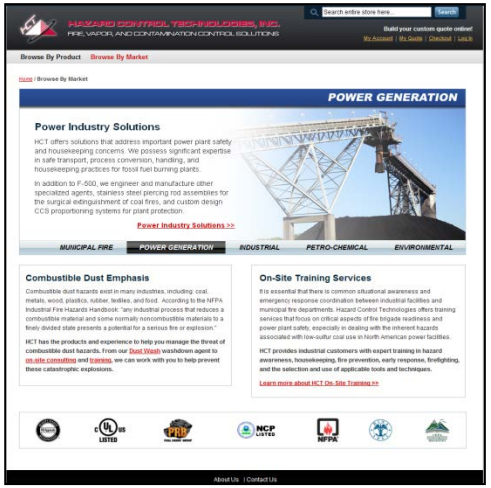
Encapsulator Agent and Lithium-ion Battery Fires

www.hct-world.com

Hazard Control Technologies, Inc.

- Headquarters -- Atlanta, GA USA
  - Chemical Solutions
  - Engineered Systems
  - Consulting & Training
  - Emergency Response
- Global Distribution
  - Europe
  - Asia
  - Australia
  - South America
- Website
  - www.hct-world.com
  - www.F-500.com





HAZARD CONTROL TECHNOLOGIES, INC.

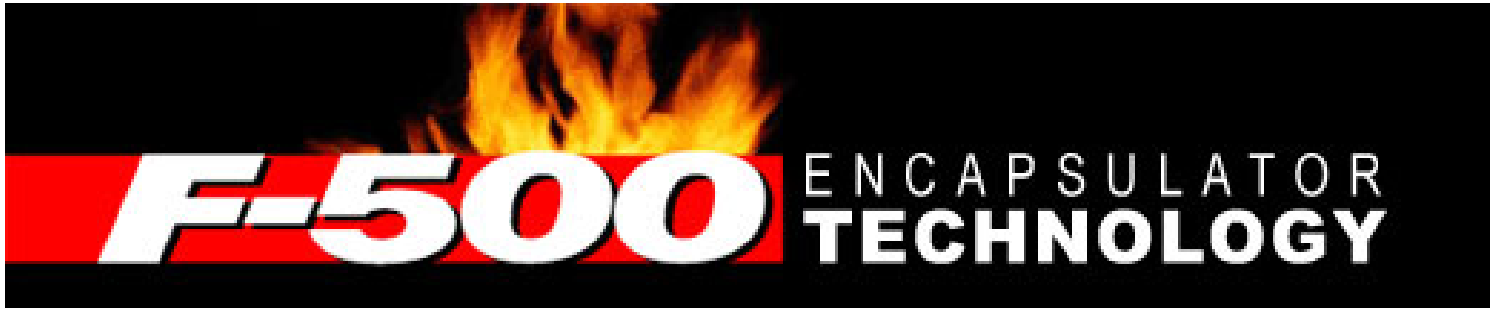
FIRE, VAPOR, AND CONTAMINATION CONTROL SOLUTIONS

Consulting and Training

High Hazard Response Emergency Training focuses on preparing firefighters with new solutions for today's more challenging fires. Course includes car fires, three-dimensional, Class B fires, Class D combustible metal fires, lithium-ion battery fires and energized transformer fires.

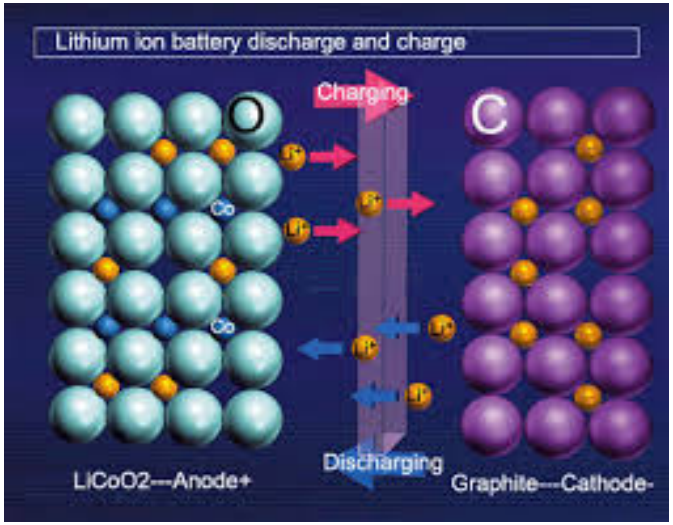
Emergency Response Consulting in the areas of combustible dust fires, providing expert recommendations for fire suppression.

Lithium-ion Battery Fires



What is a Lithium-ion Battery?

- Lithium-ion batteries are popular due to their high energy density, minimal memory effect and low self-discharge.
- A lithium-ion battery is a rechargeable battery in which lithium-ions move from the negative electrode to the positive electrode during discharge, and back when charging.



What is a Lithium-ion Battery?

- Lithium cobalt oxide – $LiCoO_2$
  - Handheld electronics
  - High energy density; safety risks

- Lithium iron phoshate – $LiFePO_4$
  Lithium-ion manganese oxide – $LiMgO_2$
  - Power tools and medical equipment
  - Lower energy density; relatively safe

- Lithium nickel manganese cobalt oxide – $LiNiMnCoO_2$ (NMC)
  - Other Lithium-ion variations
  - Automobiles
  - Generally safe, but vulnerable

Why Do Li-ion Batteries Ignite?

- High energy density leads to heat
- Li-ion batteries have flammable, pressurized electrolyte

Overheating or over charging leads to thermal runaway and cell rupture.

Safety features have been incorporated in lithium-ion batteries, including shut-down separators, vents for pressure relief and thermal interrupts, but not all cells use these features and contaminants in production and catastrophic events can overide the safety features.

Newsworthy Li-ion Battery Failures

- 2010 - Boeing 747 crash – Dubai
- 2011 – Chevy Volts catch fire during crash testing
- 2011 – Asiana Airlines 747 crash – South Korea
- 2011 – Fisker Karma coolant leak caused fire in house
- 2012 – Fisker Karma caught fire in a parking lot in California
- 2012 – Nissan catches fire after collision in China
- 2013 – Tesla Model S hit debris and caught fire in Washington
- 2013 - Tesla Model S collision caught fire in China
- 2013 - Tesla Model S collision caught fire in Mexico
- 2013 - Tesla Model S hit debris and caught fire in Tennessee
- 2014 – Boeing 787 Dreamliners grounded
- 2015 – Amazon stops hoverboard sales due to fires
- 2016 – UN Aviation Agency bans Li-ion battery shipments on passenger planes
- 2016 – 100 bikes destroyed in bike shop fire due to Li-ion eBike failure
- 2016 – Tesla in Norway catches fire while charging
- 2016 – Massachusetts police car ignites from rechargeable flashlight explosion

Lithium Battery Fire Testing

F-500 Encapsulator Agent

Lithium-ion Batteries are Multiple Classes of Fire

- Class A – plastic components
- Class B – lithium-ion salt in an organic solvent
- Class C – energized object with shock potential
- Class D – lithium (lithium batteries)

Since F-500 EA is a three-dimensional firefighting agent that rapidly cools, encapsulates hydrocarbons and interrupts the free radical chain reaction, it is well-suited to extinguishing lithium-ion battery fires.

F-500 EA Testing on Lithium-ion Batteries

2009 Bosch tested F-500 EA on li-ion battery fires and makes it their product of choice

BOSCH Invented for life

2009 Bosch shared their results at VDA with the German Automotive Industry

2010 Bosch shares their testing with Baden-Wurttemburg Fire School

2011 Baden-Wurttemburg Fire School publishes guidelines for fighting li-ion battery car fires

2011 Article about F-500 EA appears in BrandSchutz firefighting magazine second article about F-500 EA apears in BrandSchutz

2012 Dekra (worldwide vehicle testing authority) tests F-500 EA and issues report

F-500 EA Testing on Lithium-ion Batteries

2013 Dekra report published in BrandSchutz article
2013 Dekra, Deutsche ACCUmotive and Daimler present findings at SAE Conference in Detroit

2015 General Motors tests F-500 EA on lithium-ion battery fires

2016 Tesla specifies F-500 EA in battery charging area
2016 Jaguar performs lithium-ion battery testing in UK
2016 Jaguar chooses F-500 EA as their agent of choice

2017 Testing in Netherlands showed foam and powder were ineffective fighting lithium-ion battery fires. F-500 EA successfully extinguished the batteries and prevented reignition.

Netherlands - Lithium-ion Battery Fire Testing

F-500 Encapsulator Agent

F-500 EA's unique ability to extinguish lithium-ion battery fires presents many opportunities

- Municipal Fire Departments
  - Electric and hybrid car fires
  - Commercial solar/wind energy storage system fires
  - Truck or rail fires transporting li-ion batteries

- CCS systems
  - Electric and hybrid automobile manufacturers
  - Warehouses storing li-ion batteries
  - Li-ion battery manufacturers
  - Li-ion component assemblers
  - Li-ion energy storage systems

Electric and Hybrid Car Fires

F-500 EA's unique versatility makes it ideal for lithium-ion battery car fires – one agent extinguishes all parts of the car

- Lithium-ion battery car fires
  Tested and recommended specifically for lithium-ion battery car fires by Dekra, Deutsche ACCUmotive, Daimler and the Baden-Wurttemburg Fire School
- Both Polar and Nonpolar Solvents (hybrids/second vehicle accidents)
  Diesel fuel, gasoline, E10, E85
- Magnesium Components (Class D)
  Door and seat frames, dashboards, steering columns
- Tires
- Plastics

Full Scale Electric Vehicle Fire Testing

NFPA and The Fire Protection Research Foundation
June, 2013

Multiple tests were studied extinguishing lithium-ion battery car fires with water

	Gallons to Extinguish
Test 1	1274
Test 2	2639
Test 3	1165
Average	1692

One of the batteries reignited 22 hours after the test

Full Scale Electric Vehicle Fire Testing

Water can extinguish a lithium-ion car fire with an average of 1692 gallons per vehicle

Even then, NFPA warns reignition is possible and recommends extinguished vehicles be stored at least 50 feet from other vehicles or structures.

NFPA – Full Scale Testing with Lithium-ion Car Batteries

Encapsulator Agent on Lithium-ion Battery Car Fires

With 3% Encapsulator Agent in solution, you can extinguish a lithium-ion battery car fire with 20-25% less water, and not be concerned with reignition.

Encapsulator Agent will not have electrical feedback to the nozzle from 350 volt lithium-ion car batteries

Enccapsulator Agent will have no flare-ups or explosions when applied to lithium-ions or the escaping hydrogen gas.

And Encapsulator Agent is the best agent around for the rest of the car fire, magnesium components, tires or spilled fuel (from the other car).

Note: Foam will not cool or penetrate the housing of a lithium-ion car battery and could result in electrical feedback to the nozzle

F-500 Encapsulator Technology
Fire Suppression Mechanics

- Surface Tension Reduction
  - Common to all fire suppression agents
- Rapid and Permanent Heat Reduction
- Encapsulation
- Interruption of the Free Radical Coalescence

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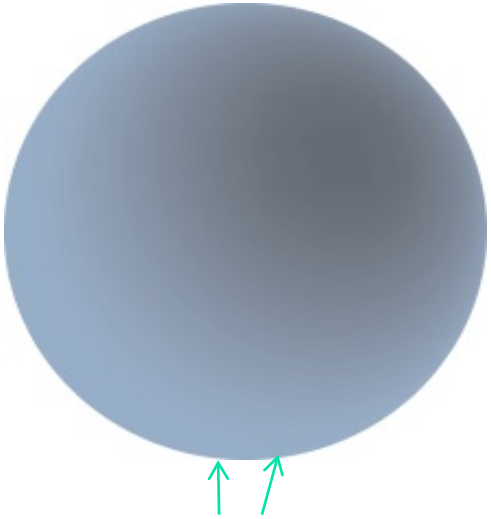
FIRE, VAPOR, AND CONTAMINATION CONTROL SOLUTIONS

F-500 ENCAPSULATOR TECHNOLOGY

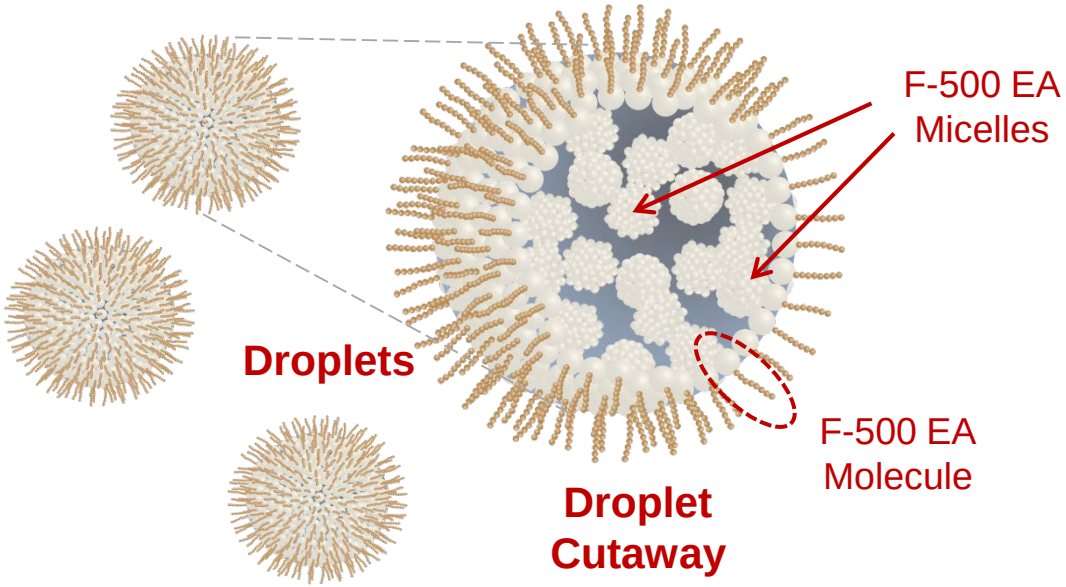
Water Droplet



H_2O Molecules

F-500 EA Droplets

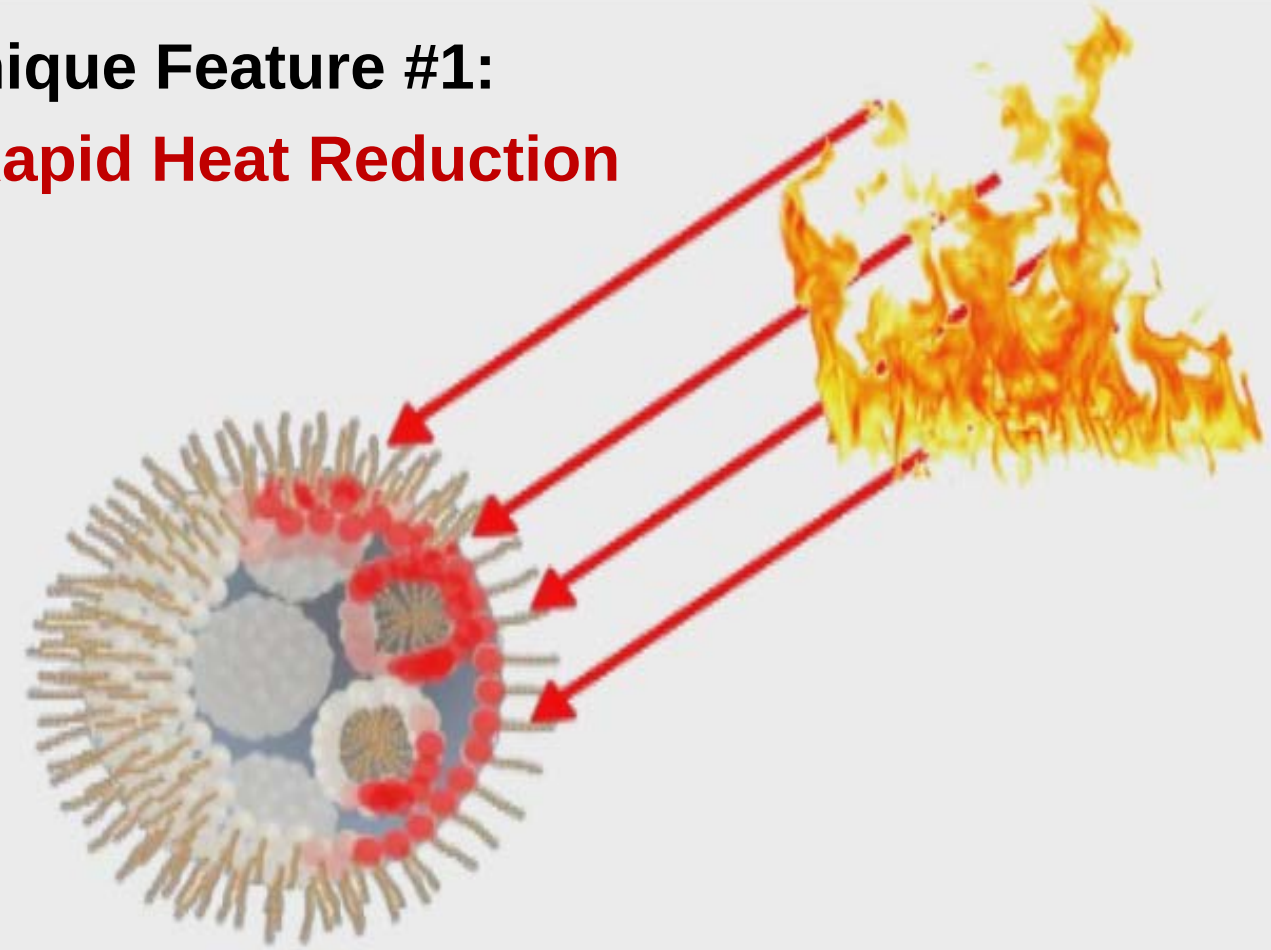
When a droplet is formed, nonpolar tails stick out of the water droplet, pulling the polar heads to the surface to form an F-500 EA skin on each droplet.



Droplet	Molecular Weight	Boiling Point	Heat Reduction Method	Efficiency
Water	18 g/mol	212^{0}F (100^{0}C)	Steam Conversion	Inefficient
F-500 EA	>1000 g/mol	248^{0}F (120^{0}C)	Thermal Conveyance	Highly Efficient

Unique Feature #1:

Rapid Heat Reduction



F-500 EA Droplet is creating a thermal circuit, where heat is driven into the internal portion of the droplet.

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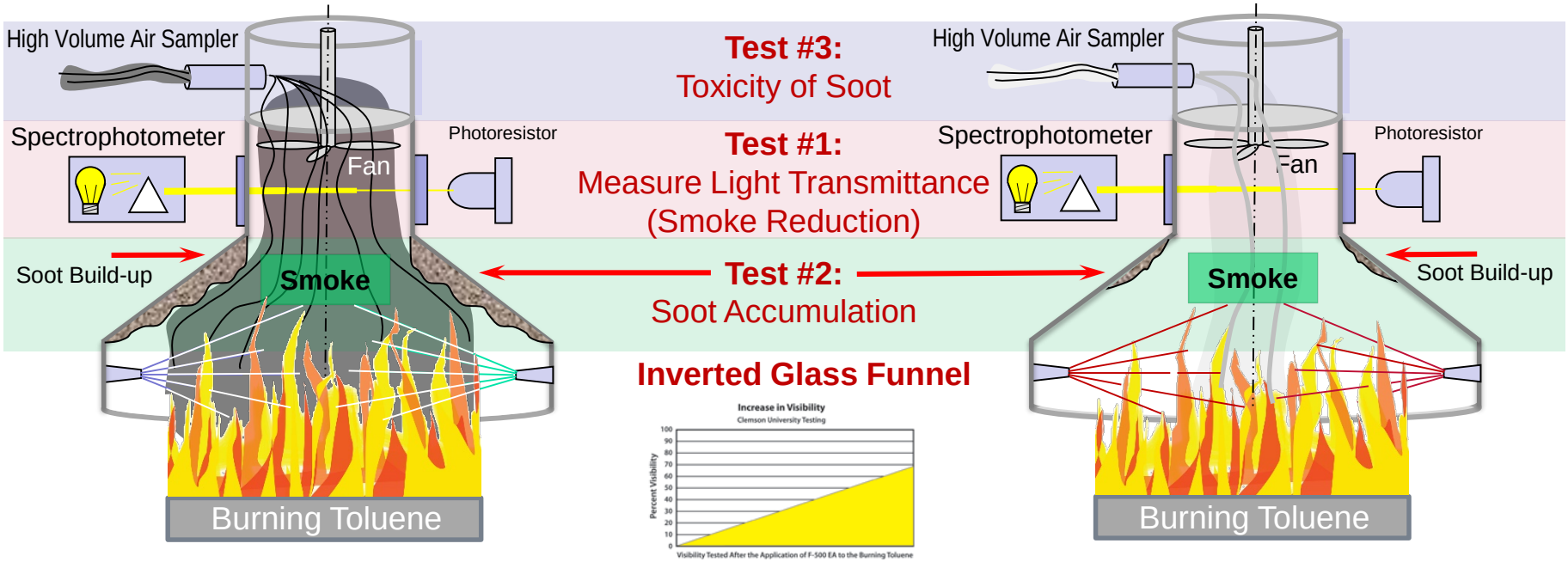
F-500 ENCAPSULATOR TECHNOLOGY

Unique Feature #3: Interruption of Free Radicals*

** When free radicals combine or "come together", they form soot and smoke*



Water Spray
First Test Series
Water Sprayed
Through Smoke Plume

Plain Water vs. 3% F-500 EA	
1. Light Transmittance (Smoke Reduction)	68% Increase in Visibility
2. Soot Accumulation	97% Reduction in Soot
3. Soot Toxicity	98.6% Reduction in Toxicity

F-500 EA Spray
Second Test Series
F-500 Encapsulator Agent @3%
Sprayed Through Smoke Plume

Clemson University Study – Pendelton, SC

Types of CCS Systems

- Bladder Tank System
- Water Driven Proportioner System
- Balanced Pressure Pump System

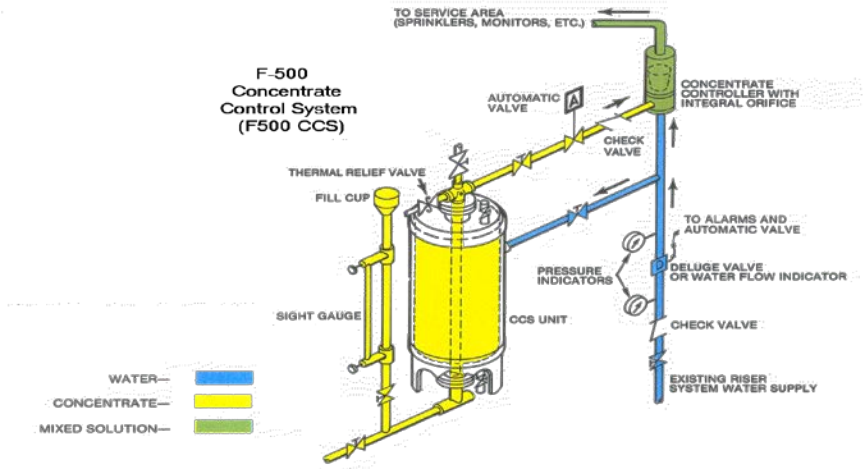
F-500 EA Concentrate Control Supply (CCS) Systems

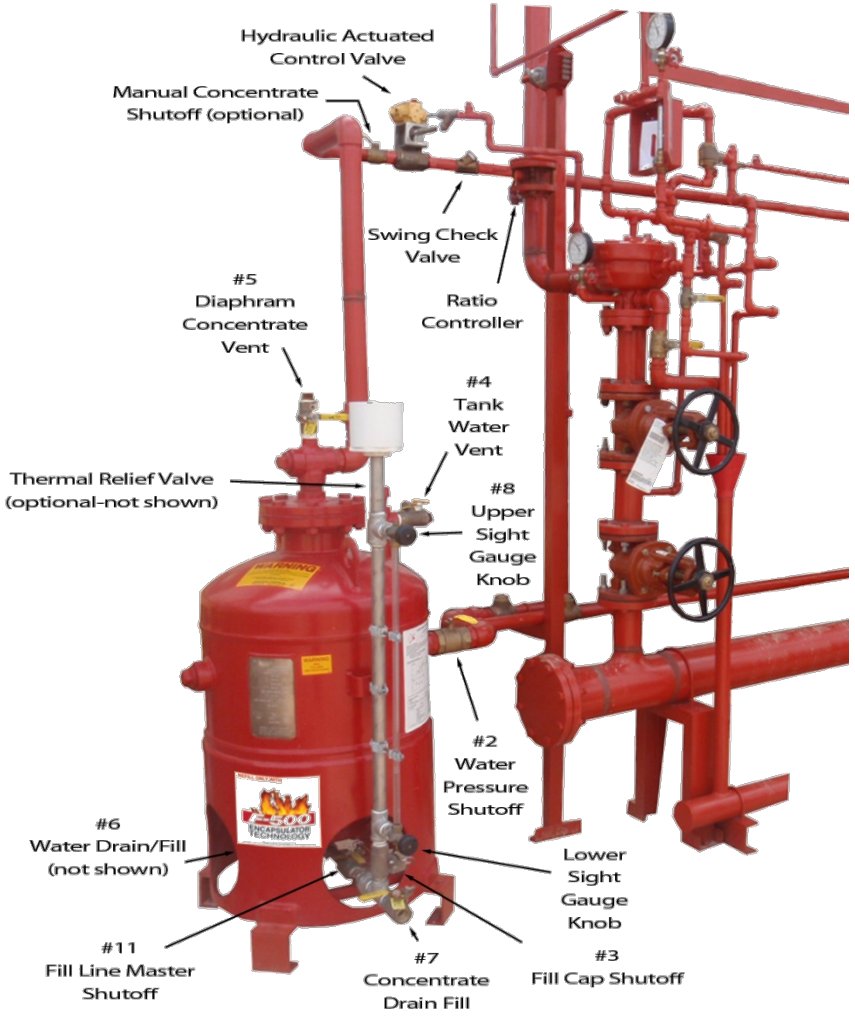
Bladder Tank System

Agent concentrate is stored in a rubber bladder inside a steel vessel (pressurized or non-pressurized) and is connected to the water riser by a ratio controller. Upon discharge, part of the water from the riser is redirected to the steel vessel, squeezing the bladder, pushing out the agent concentrate into the ratio controller. This system has fewer parts and requires less maintenance than the other systems. No external energy is required to operate.

Bladder Tank

- Steel vessel with rubber bladder
- Ratio controller
- Actuation valve (manual, hydraulic or electric)





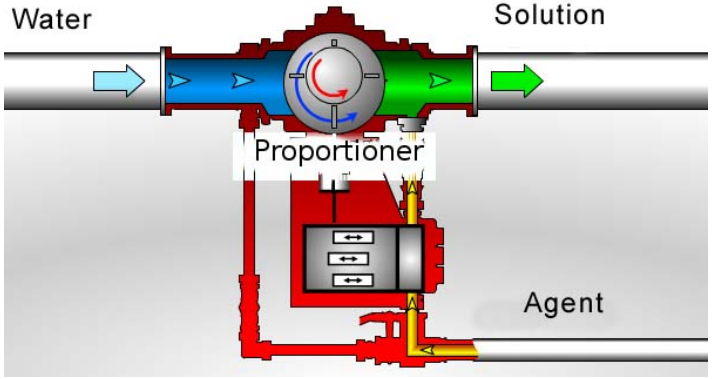
F-500 EA Concentrate Control Supply (CCS) Systems

Water Driven Proportioner System

The Water Driven Proportioner is a mechanical device that uses the water flow from the riser to rotate a small pump that sucks the agent concentrate from a non-pressurized container and delivers it to the riser at the desired concentration. This system is generally smaller than the bladder tanks, but more expensive. This system is ideal for applications with only one proportioning point.

Water Driven Proportioner (WDP)

- Poly tank
- WDP



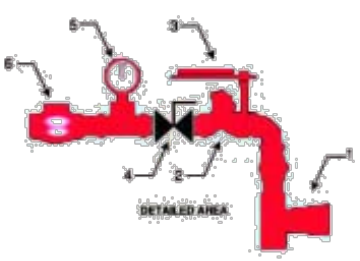
F-500 EA Concentrate Control Supply (CCS) Systems

Balanced Pressure Pump System

A Balanced Pressure Pump System uses a dedicated electric pump and a balancing diaphragm valve to pump the agent from a non-pressurized tank into a ratio controller. These systems require electrical controls and sensing equipment, making them more expensive and requiring more maintenance, but they can handle larger systems while being able to refill during a discharge.

Balanced Pressure Pump (BPP)

- Poly or steel tank
- Ratio controller
- Pressure balancing diaphragm
- Controls



1. PROPORTIONER
2. PRESSURE BALANCING VALVE
3. DUPLEX GAUGE
4. CONCENTRATE VALVE
5. PRESSURE GAUGE
6. CHECK VALVE

CCS System Customers

Hundreds of CCS systems have been installed protecting transformers, turbines, warehouses, paint, coal, fly ash and dust collectors. Recent installations have been installed protecting companies involved with lithium-ion batteries.

- Bosch
- Automotive manufacturers
  - Three manufacturers in US
  - Two manufacturers in Europe

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F-500 ENCAPSULATOR TECHNOLOGY

Encapsulator Agent
NFPA 18A - New 3rd Category of Agents

PINNACLE
F-500 ENCAPSULATOR TECHNOLOGY

Foam and/or Encapsulator Agent Applications

- Class A Fires, 2D
- Class B, 2D Fires (Gas, Diesel or Ethanol-blended Fuels)
- Class K or Class F Fires

Encapsulator Agent Applications - Expands Your Hazard Mitigation Capabilities

F-500 ENCAPSULATOR TECHNOLOGY

- Class A, 3D Fires
- Class B, 3D Fires (Transformers, Turbine Lube Oil Fires)
- Class B, Flowing/Spraying Fuel Fires (Distillation Columns, Flange Fires)
- Class C Fires (FDNY/ConEdison Testing - SOGs)
- Class D Fires (Magnesium, Lithium-ion Batteries)
- Flammable Liquid Spill Control

The only agent proven to extinguish lithium-ion batteries, without reignition, and recommended for energized transformer fires.

Summary

- Encapsulator Agents are Unique
  - Encapsulates hydrogen gases
  - Rapidly cools battery housings and cells
  - Inhibits smoke
- Unsurpassed for Lithium-ion Battery Fires
  - Lithium-ion battery car fires
    - Extinguishes with 20-25% less than plain water
    - No reignition
  - Fixed suppression systems
- No other agent can do this

F-500 ENCAPSULATOR TECHNOLOGY

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Thank You For Your Attention

Any Questions?

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