NFPA 18A

Standard on Water Additives for Fire Control and Vapor Mitigation[i]

2022

Section 7.7

Appendix A, Chapter 4

7.7 Encapsulator — Spherical Micelle Stability Test (Liquid Phase Fuels).

7.7.1 General[ii].

This section shall cover test procedures to evaluate the ability of a water additive solution to form and maintain stable spherical micelles capable of encapsulating combustible and flammable liquids (nonpolar and polar), rendering the flammable liquids nonflammable, nonignitable, and nonexplosive and maintaining that encapsulation in the presence of high heat over an extended period of time.

7.7.2 Test Materials.

7.7.2.1

The following materials shall be provided for the test:

(1) [iii]Steel or aluminum pan, square or round, at least 4.8 mm thick and 200 mm high, with a surface area of 4.6 m^2
(2) Amount of water additive concentrate as shown in **Table 7.7.3**
(3) Type of fuel selected to be tested from the fuels specified in **7.7.2.2**
(4) Amount of fuel as shown in **Table 7.7.3**
(5) Water supply capable of dispensing through a nozzle the amount of water shown in **Table 7.7.3**
(6) 20 L/min nozzle
(7) Ignition source consisting of a propane torch producing a minimum 25 mm flame

7.7.2.2

The following fuels shall be tested:

(1) Nonpolar fuels
- (a) Heptane
- (b) Gasoline as defined in 40 CFR 86.113-94
- (c) Gasoline with 10 percent ethanol
- (d) Gasoline with 18 percent methyl tertiary butyl ether (MTBE)
- (e) No. 2 diesel
- (f) Jet A
- (g) Others

(2) Polar fuels
- (a) Alcohol
- (b) Ethanol
- (c) Ethanol blends (E15, E85, other)
- (d) Other

7.7.3[iv] Test Method Procedure.

The encapsulator — spherical micelle stability test shall be set up as follows:

(1) The test pan shall be thoroughly washed with clean water and dried.

(2) Using the individual test fuel selected from **7.7.2.2**, the full amount of fuel shown in **Table 7.7.3** shall be poured into the pan.

(3) The full amount of water additive concentrate shown in **Table 7.7.3** shall be mixed into the fuel within 1 minute.

(4) Within 1 minute of adding the fuel and water additive concentrate, the full amount of water shown in **Table 7.7.3** shall be added using a 20 L/min nozzle and in a manner to agitate the resulting mixture. Following addition of the water, agitation is to be stopped.

(5) Following the addition of water, agitation shall be stopped.

Table 7.7.3 Encapsulator — Spherical Micelle Stability Test		
Item	**Mix Ratio (Part)**	**SI Units**
Water additive	1	Manufacturer's recommendation
Fuel (7.7.2.2)	Fuel ratio = Fuel amount/water additive amount	Manufacturer's recommendation
Water	Water ratio = Water amount/water additive amount	Manufacturer's recommendation
Kinetic energy — Through agitation of water additive and fuel with water hose stream nozzle over a full 1-minute period.		

7.7.4 Ignition Test Procedures.

7.7.4.1 General.
Ignition tests for each fuel selected for testing and listing from **7.7.2.2** shall be acceptance tested in accordance with **7.7.4.2** and **7.7.4.3**.

7.7.4.2 One-Minute Ignition Test.

7.7.4.2.1
One minute after completion of agitation, the ignition torch described in **7.7.2.1(7)** shall be passed over the entire liquid surface, including corners, with the tip of the flame impinging on the surface, in an attempt to re-ignite the fuel.

7.7.4.2.2
The fuel shall not partially or fully ignite while the torch is being passed over the fuel.

7.7.4.3 Two-Hour Ignition Test.

7.7.4.3.1
Two hours after completion of agitation, the ignition torch described in **7.7.2.1(7)** shall be passed over the entire liquid surface, including corners, with the tip of the flame impinging on the surface, in an attempt to re-ignite the fuel.

7.7.4.3.2
The fuel shall not partially or fully ignite while the torch is being passed over the fuel.

7.7.5[v] Acceptance and Listing.
When the requirements of **7.7.4.2** and **7.7.4.3** have been successfully met for the selected and tested fuel from **7.7.2.2**, the water additive concentrate shall be considered an acceptable encapsulator for the specific fuel tested.

A.4.3

Lithium-ion battery and lithium-ion battery energy storage system (BESS) fires are unique electrochemical fire hazards that involve multiple fire classes (Class A, Class B, Class C, Class D) within one entity. While BESS are covered by NFPA 855, it should be noted that lithium-ion battery fires as a stand-alone hazard are not currently addressed in any NFPA standard. According to NFPA research reports, copious amounts of plain water are required to extinguish lithium-ion battery fires, and they can still exhibit thermal runaway up to 72 hours after initial extinguishment.

Water additive based on spherical micelle technology (encapsulator agents) conforming to Section **7.7** has been tested extensively by independent third-party testing organizations, including Kiwa, Dekra, Daimler, Dutech, Bosch, Fraunhofer University, and TU Clausthal. This testing has been controlled, scientific, and highly instrumented, documenting fire suppression, control and elimination of thermal runaway, and encapsulation of both flammable electrolyte and other explosive off-gases, rendering them nonexplosive. Encapsulating technology reduces the toxicity of HF gas exposure to humans.

In addition, the copious amounts of water used to suppress lithium-ion battery fires create copious amounts of run-off containing hydrofluoric acid, creating an environmental issue and expensive HAZMAT disposal cost. Compared to water, water additive solution uses a reasonable amount of solution and has been documented to modify the chemistry of the run-off, making it suitable for additional dilution and disposal in a municipal water treatment plant. Testing documentation can be found in the NFPA Research Library and Archives.

A.4.3.6(1)

Some examples of liquid fuel spill locations include, but are not limited to, fuel spillage on roads from auto accidents, tanker rollovers, train derailments, gas stations, refineries, loading facilities, and airport tarmacs. For a combustible and flammable liquid spill, an encapsulator agent meeting Section **7.7** can be applied to encapsulate the fuel inside a stable spherical micelle to remove the flammability of the fuel.

Using the example encapsulator agent mix ratios shown in **A.7.7.3**, the fuel neutralization application rate would be a ratio of fuel/water with the encapsulator agent solution being applied at the concentrate's proportion rate. Using an example of 20 L of fuel spilled, the ratio of fuel/water = 8/40, which reduces to 1/5. Therefore, 20 L of fuel × 5 = 100 L of a 2.5 percent encapsulator agent solution would be agitated into the 20 L of fuel to encapsulate and neutralize the fuel. An LEL gas detection meter can be used to show total encapsulation and neutralization. As a double check, if 100 L of 2.5 percent encapsulator agent would have applied 2.5 L of encapsulator agent, then 2.5 L of encapsulator agent × 8 (mix ratio of water additive to fuel) equals 20 L.

[i] NFPA 18A: Standard on Water Additives for Fire Control and ..., https://www.nfpa.org/codes-and-standards/all-codes-and-standards/list-of-codes-and-standards/detail?code=18A.

[ii] **A.7.7.1**

An emulsifying agent is one that is capable of rendering the fuel nonflammable by encapsulating the hydrocarbon molecules.

[iii] **A.7.7.2.1(1)**

To meet the 4.6 m^2 pan surface area, the round test pan should have a diameter of 770 mm, and the square test pan should be 690 mm by 690 mm.

[iv] **A.7.7.3**

The basic building block of an encapsulator agent is a spherical micelle. A spherical micelle is a molecular structure (i.e., molecular chemical cocoon, molecular vault) capable of encapsulating fuel molecules, thus separating the fuel from the oxygen on a chemical/molecular level and rendering the fuel nonflammable, nonignitable, and nonexplosive. Spherical micelles encapsulate fuel molecules regardless of whether the fuel molecules are in the liquid phase or vapor phase. They can encapsulate a variety of fuels such as carbons and hydrocarbons (nonpolar and polar). While this test might at first appear to neutralize the flammability of the fuel, the test actually uses the fuel to determine whether an agent can form stable spherical micelles capable of the following:

(1) Encapsulating the fuel and separating the fuel from the oxygen
(2) Remaining stable in the presence of high heat — the 1-minute ignition test
(3) Remaining stable in the presence of high heat over an extended period of time — the 2-hour ignition test

In the encapsulator — spherical micelle stability test, an agent could use the mix ratio in **Table A.7.7.3** to document stable spherical micelle encapsulation of a fuel (heptane, ethanol blended fuel, etc.).

[v] **A.7.7.5**

Since the ratio of water additive/water shown in **Table 7.7.3** is 1 part water additive/40 parts water = 2.5 percent, the water additive can be listed as an acceptable encapsulator for the fuel tested at a water additive concentration/proportion rate of not less than 2.5 percent and water additive solution not less than 2.5 percent.