

RESEARCH AND DEVELOPMENT TECHNICAL REPORT ABSTRACT

# Comparative fire performance tests using water and antifreeze solutions discharged from standard spray sprinklers

**Author(s)**

Kerry Bell

Jeff Hebenstreit

Pravinray Gandhi

Kelly Opert

Ben Gaudet

**Email**

[Kerry.M.Bell@ul.com](mailto:Kerry.M.Bell@ul.com)

[Jeffrey.R.Hebenstreit@ul.com](mailto:Jeffrey.R.Hebenstreit@ul.com)

[Pravinray.D.Gandhi@ul.com](mailto:Pravinray.D.Gandhi@ul.com)

[Kelly.Opert@ul.com](mailto:Kelly.Opert@ul.com)

[Benjamin.Gaudet@ul.com](mailto:Benjamin.Gaudet@ul.com)



## Abstract

A series of fire tests were conducted in UL's fire test facilities located in Northbrook, IL to determine the effectiveness of sprinklers discharging water compared to certain antifreeze solutions currently referenced in the NFPA 25 standard for Inspection, Testing and Maintenance of Water-Based Fire Protection Systems, [1]. The primary focus of this research initiative was to develop comparative test data related to fires that may originate in a light hazard occupancy; however, comparative data was also developed using an existing fire test protocol utilized for sprinklers intended for use in the NFPA 13 standard for the Installation on Sprinkler Systems, [2] that relates to an ordinary hazard occupancy. Lastly, additional exposure to fire tests beyond those described in previous antifreeze research initiatives were conducted on antifreeze solutions currently referenced in NFPA 25 and are included in this report.

In order to compare fire test performance related to a light hazard occupancy, a fuel package was developed that (1) had fire size characteristics similar to an office workstation type fire and (2) could be controlled with sprinklers discharging water at a density of 0.10 gpm/ft<sup>2</sup>, which is the density that is referenced in NFPA 13 for light hazard occupancy protection.

The sprinkler system consisted of a total of 36 upright standard spray sprinklers having a nominal discharge coefficient of 5.6 gpm/psi<sup>1/2</sup> installed on a 14 ft x 14 ft spacing with the deflectors located approximately 3 in. below the ceiling. The sprinkler piping was arranged in a "tree" branch line configuration with sufficient supply and branch line piping to accommodate a total volume of approximately 500 gallons of antifreeze solution. A total of six tests were conducted using the light hazard fuel package located between two sprinklers on separate branch lines.

Three tests were conducted using a nominal sprinkler discharge density of 0.10 gpm/ft<sup>2</sup> for the duration of the test, which correlated to a discharge pressure of 12.3 psig for water. One test was conducted using water as a wet system, one test was conducted using water as a simulated dry system, and one test was conducted with 500 gallons of a 50 percent (by volume) glycerin antifreeze solution followed by water. During the test using water in a wet system, a total of four sprinklers operated compared to 12 sprinklers that operated during the test using the glycerin solution followed by water. During the simulated dry system testing with water, a total of 10 sprinklers operated.

Three tests were conducted using a higher sprinkler discharge pressure, based on a nominal 24 psig discharge pressure for water, to simulate a higher starting pressure for a sprinkler system that was hydraulically designed for a 0.10 gpm/ft<sup>2</sup> discharge density. One test was conducted with water, one test was conducted with approximately 500 gallons of a 50 percent glycerin antifreeze solution followed by water, and one test was conducted with 500 gallons of a 38 percent glycerin antifreeze solution followed by water. During the test using water, a total of two sprinklers operated compared to seven sprinklers that operated during the test using the 50 percent glycerin and five sprinklers that operated during the test using the 38 percent glycerin solution.



## WHITE PAPER

For sprinkler systems protecting an ordinary hazard occupancy using an antifreeze solution volume greater than 40 gallons, UL 2901, the Standard for Antifreeze Solutions for use in Fire Sprinkler Systems[3], requires fire testing using a fuel package described in UL 199, the Standard for Automatic Sprinklers, [4]. This fire test is used by UL to certify most standard spray sprinklers. For this testing, four open sprinklers were arranged to discharge either water only or antifreeze solutions followed by water onto the fire. The nominal sprinkler discharge density used for this UL 199 fire test is 0.15 gpm/ft<sup>2</sup> and the sprinklers are required to control the fire such that the ceiling temperature above the fire is generally maintained below a nominal 600 °F after 5 minutes of water discharge. Three tests were conducted; one using water, one using 38 percent glycerin antifreeze solution followed by water and one test using a 30 percent propylene glycol antifreeze solution followed by water. During the three tests, the ceiling temperature was reduced to below 600 °F after 5 minutes of water discharge compared to approximately 1450°F for the glycerin solution and 1350°F for the propylene glycol solution prior to being followed with water. At the time of publication of this report, there were no antifreeze solutions that are UL Listed for ordinary hazard occupancy applications with system volumes greater than 40 gallons.

For all tests with the antifreeze solutions, the test pressure was adjusted due to the difference in density between antifreeze and water to maintain the required flow rate and discharge density.

A description of the test parameters and results for the light hazard type tests is provided in Table 1. A graphical presentation of the ceiling temperatures for the ordinary hazard type fire tests are described in Figure 1.

Currently, UL 2901 describes three types of fire tests as follows:

- Exposure to fire (evaluates the antifreeze solution for resistance to ignition and substantial contribution to the fire)
- Fire fighting effectiveness — Residential dwelling units
- Fire fighting effectiveness — Ordinary hazard occupancies, UL 199 - 350 lb Wood Crib Fire Test for sprinkler systems with volumes greater than 40 gallons.

Tables 2-4 provide information on the results of the fire testing that has been conducted on the legacy NFPA 13 glycerin and propylene glycol antifreeze solutions using the three UL 2901 fire tests and the light hazard fire test described herein as compared the acceptance criteria that is required for UL Listing. For ordinary hazard occupancy applications using an antifreeze solution volume greater than 40 gallons, UL 2901 requires fire testing using a fuel package described in UL 199.



## Summary

The series of tests demonstrated differences in performance between concentrations and types of antifreeze solutions as compared to water at the same discharge densities. In general, the following observations were made based on the data contained in this report:

- The ceiling temperatures during the light hazard fire testing with antifreeze solutions were higher and the number of operating sprinklers was greater as compared to water.
- The ceiling temperatures during the ordinary hazard fire testing with antifreeze solutions did not significantly decrease until the transition from antifreeze to water occurred during the test.

The results from the tests imply that the antifreeze solution concentration and fire size impact the performance as compared to water. As the concentration of the antifreeze solution increases or as the fire size increases, the difference in performance is greater.

---

## References

1. National Fire Protection Association. (2020). NFPA 25, Standard for the Inspection, Testing, and Maintenance of Water-Base Fire Protection Systems
2. National Fire Protection Association. (2019). NFPA 13, Standard for the Installation of Sprinkler Systems.
3. Underwriters Laboratories Inc. (2020). Standard for Safety for Antifreeze Solutions for Use in Fire Protection Systems, UL 2901.
4. Underwriters Laboratories Inc. (2020). Standard for Safety for Automatic Sprinklers for Fire-Protection Service, UL 199.
5. Antifreeze Systems in Home Fire Sprinkler Systems — Literature Review and Research Plan, Fire Protection Research Foundation, June 2010.
6. Antifreeze Systems in Home Fire Sprinkler Systems — Phase II Final Report, Fire Protection Research Foundation, December 2010.
7. Antifreeze Solutions Supplied through Spray Sprinklers — Final Report, Fire Protection Research Foundation, November 2012.

Table 1: Light hazard occupancy fire test summary table

FIRE TEST REFERENCE	No. 1	No. 2	No. 3	No. 4	No. 5	No.6
Test code	07222005	08192002	07302003	07232002	07232003	07312004
<b>PARAMETERS</b>						
Fuel Package	Four UL 199 ECLH Fire Test Cribs Ignited by Heptane (96 oz)					
Ceiling Height, ft	10					
Nominal Clearance, ft	7.2					
Ignition Location	Between 2 Offset on Separate Branch Lines					
Sprinkler Type	Upright Standard Spray, Standard Coverage					
Sprinkler Response Type	Quick Response 3 mm Bulb					
Temperature Rating, °F	175					
Nominal Sprinkler Discharge Coefficient K, gpm/psi <sup>1/2</sup>	5.6					
Sprinkler Spacing, ft x ft	14 x 14					
Deflector to Ceiling, in	3					
Liquid Type Discharged	Water — Wet system	Water — Dry system**	50% Glycerin followed by water	Water — Wet System	50% Glycerin followed by water	38% Glycerin followed by water
Nominal Total Volume of Antifreeze, gal	0	0	500	0	500	500
Nominal Discharge Pressure, psig	12.3	12.3	13.9	24*	27.2*	26.4*
Target Flow, gpm	19.6	19.6	19.6	27.4	27.4	27.4
Target Discharge Density, gpm/ft <sup>2</sup>	0.10	0.10	0.10	0.14	0.14	0.14
<b>RESULTS</b>						
Length of Test, min:s	15:00	15:00	15:00	6:00	15:00	15:00
First Ceiling Sprinkler Operation, min:s	00:35	00:43	00:43	00:39	00:37	00:44
Last Ceiling Sprinkler Operation, min:s	02:14	01:51	03:02	00:45	02:57	02:06
Number of Operated Sprinklers	4	10	12	2	7	5
Nominal Area of Sprinkler Operation, ft <sup>2</sup>	784	1960	2352	392	1372	980
Peak Gas Temperature 6 in. Below the Ceiling Above Ignition, °F	707	1130	1213	694	1373	1069
Maximum 1 Minute Average Gas Temperature 6 in. Below the Ceiling Above Ignition, °F	646	941	1089	615	1288	952
Maximum Steel Temperature, °F	282	493	513	205	639	432
Maximum 1 Minute Average Steel Temperature Above Ignition, °F	262	397	469	192	579	397

\*To simulate higher system starting pressure.

\*\* 60 second delay in water delivery from time of first activated sprinkler.

Note: The fuel package was also evaluated with water under 1 sprinkler and between 4 (Test Codes 08192003 and 08032003). In each, 5 or fewer sprinklers activated.

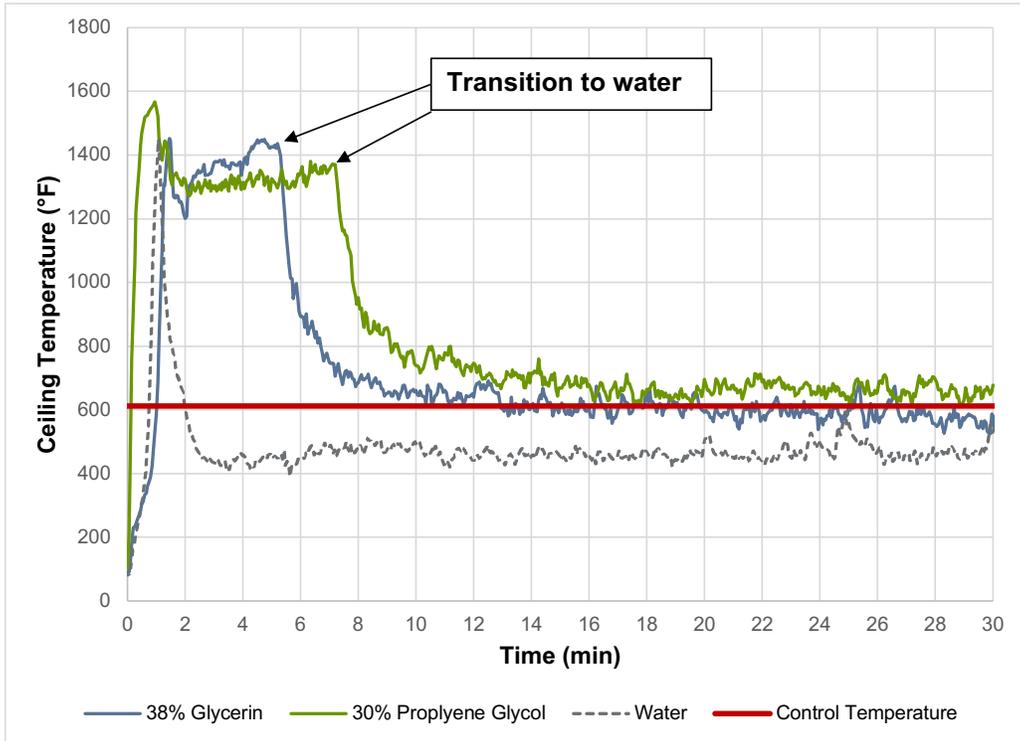


Figure 1: Ceiling temperature from the UL 199 - 350 lb Wood Crib Fire Test with 38% glycerin, 30% propylene glycol and water

Table 2: Summary of UL’s antifreeze research – Exposure to fire

Test	UL Acceptance Criteria Listed Antifreeze Solutions	Test Details	Test Results			
			38% Glycerin	50% Glycerin	30% Propylene Glycol	40% Propylene Glycol
Exposure to fire (Evaluates the resistance to ignition and substantial contribution to the fire)	Not more than a 40% increase above the maximum running 15 s average total heat release rate for the nominal 3,000 kW base fire	Test 1 - Nominal K=4.2 SSP 8 ft. ceiling	Compliant — 24.0% increase	Noncompliant — 84.1 % increase [7]	Compliant - 18.4% increase	Not tested – Assumed Noncompliant based upon 50% glycerin test results
		Test 2 - Nominal K=4.2 SSP 20 ft. ceiling	Compliant — 26.9% increase	Noncompliant — >230%* increase [7]	Compliant — 8.5% increase	Not tested – Assumed Noncompliant based upon 50% glycerin test results
		Test 3 - Nominal K=8.0 SSP 8 ft. ceiling	Compliant — 24.1% increase	Compliant — 28.6 % increase [7]	Compliant — 12.9% increase	Not tested – Assumed Compliant based upon 50% glycerin test results
		Test 4 - Nominal K=8.0 SSP 20 ft. ceiling	Compliant — 13.7% increase	Noncompliant — >230%* increase [7]	Compliant — 13.8% increase	Not tested – Assumed Noncompliant based upon 50% glycerin test results

\*The calorimeter is calibrated to a maximum of 10 MW, an increase of 230% over the nominal 3MW base line fire.

Table 3: Summary of UL's antifreeze research – Residential and light hazard

Test	UL Acceptance Criteria Listed Antifreeze Solutions	Test details	Test Results			
			38% Glycerin	50% Glycerin	30% Propylene Glycol	40% Propylene Glycol
<b>Fire fighting effectiveness — Residential dwelling units</b>	Temperature acceptance criteria and not more than 2 operated sprinklers	Test 1 – Nominal K=4.9 Pendent Residential Sprinkler, Low Flow	Compliant based upon 50% test results	Compliant [6]	Compliant based upon 40% test results	Compliant [6]
		Test 2 – Nominal K=4.9 Pendent Residential Sprinkler, 100 psig	Compliant based upon 50% test results	Compliant at 80 and 150 psig [6]	Not tested — Assumed compliant based upon glycerin test results	Not tested — Assumed compliant based upon glycerin test results
		Test 3 – Nominal K=4.2 Sidewall Residential Sprinkler, Low Flow	Compliant based upon 50% test results	Compliant [6]	Not tested — Assumed compliant based upon glycerin test results	Not tested — Assumed compliant based upon glycerin test results
		Test 4 – Nominal K=4.2 Sidewall Residential Sprinkler, 100 psig	Compliant based upon 50% test results	Compliant at 80 and 150 psig [6]	Not tested — Assumed compliant based upon glycerin test results	Not tested — Assumed compliant based upon glycerin test results
<b>Fire Fighting Effectiveness — Light hazard occupancies</b>	Not more than 10 operated sprinklers	Test 1 - Nominal 5.6 SSU Sprinklers, 14 ft. by 14 ft. spacing, 12.3 psig, 175 °F Temperature Rating	Not tested	Noncompliant — 12 Operated Sprinklers	Not tested	Not tested
	Not more than 4 operated sprinklers	Test 2 - Nominal 5.6 SSU Sprinklers, 14 ft. by 14 ft. spacing, 24 psig, 175 °F Temperature Rating	Noncompliant — 5 Operated Sprinklers	Noncompliant — 7 Operated Sprinklers	Not tested	Not tested

Table 4: Summary of UL's antifreeze research - Ordinary hazard

Test	UL Acceptance Criteria Listed Antifreeze Solutions	Test details	38% Glycerin	50% Glycerin	30% Propylene Glycol	40% Propylene Glycol
<b>Fire fighting effectiveness -- Ordinary hazard occupancies, UL 199 350 lb Wood Crib Fire Test for Sprinklers for greater than 40 gallons<sup>1</sup></b>	Gas ceiling temperature above fire to be reduced to below 530 °F plus ambient temperature	Single test with four open, nominal 5.6 SSP sprinkler installed on 10 ft by 10 ft. spacing, 15 gpm/sprinkler	Noncompliant- 1462 °F versus 622 °F control temperature	Not tested – Assumed noncompliant based upon 38% test results	Noncompliant - 1380 °F versus 632 °F control temperature	Not tested – Assumed noncompliant based upon 30% test results

Note 1: At the time of publication of this report, there were no listed antifreeze solutions for ordinary hazard occupancies for volumes greater than 40 gallons

To learn more about fire sprinkler testing and certification visit us [here](#) or contact us directly at [buildinglifesafety@ul.com](mailto:buildinglifesafety@ul.com).



**UL.com**

© 2020 UL LLC. All rights reserved. This white paper may not be copied or distributed without permission. It is provided for general information purposes only and is not intended to convey legal or other professional advice.