Antifreeze Solutions Supplied through Spray Sprinklers

Interim Report

Prepared by:

Code Consultants, Inc.

THE FIRE PROTECTION RESEARCH FOUNDATION
Research in support of the NFPA mission

FIRE RESEARCH

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FOREWORD

This Interim Report provides information on a fire test program recently completed by the Foundation to investigate antifreeze solutions supplied through spray sprinklers. Previous research by the Foundation investigated the use of antifreeze solutions only in residential sprinkler systems. As specifically requested by the NFPA Standards Council, the Foundation has completed this additional research to address a gap in the existing data by extending the data set to include spray (commercial) sprinklers. The current research was developed to investigate the potential for ignition of antifreeze supplied through non-residential, spray sprinklers. The scope of the project does not include investigating the effectiveness of the antifreeze sprays in controlling a fire condition.

The content, opinions and conclusions contained in this report are solely those of the authors.

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This Interim Report provides information on a fire test program recently completed by the Fire Protection Research Foundation to investigate antifreeze solutions supplied through spray sprinklers. Previous research by the Foundation investigated the use of antifreeze solutions only in residential sprinkler systems. As specifically requested by the NFPA Standards Council, the Foundation has completed this additional research to address a gap in the existing data by extending the data set to include spray (commercial) sprinklers.

A. Prior Foundation Research

In 2010 the Foundation completed a research project to investigate the potential for large-scale ignition of antifreeze solutions discharged from residential sprinklers and the influence of antifreeze solutions on the effectiveness of residential sprinkler systems in controlling a fire condition and maintaining tenable conditions for egress. [1] [2] Testing was conducted in two parts. Scope A consisted of fire tests using six (6) models of residential sprinklers at elevations of 8 ft and 20 ft to investigate the potential for large-scale ignition of antifreeze sprays at pressures ranging from 10 psi to 150 psi. Scope B consisted of room fire tests, similar to UL 1626, that were designed to investigate the effectiveness of sprinklers discharging antifreeze solutions and their ability to maintain tenable conditions in a sample residential fire scenario.

Results of the Scope A testing indicated that concentrations of propylene glycol exceeding 40% by volume and concentrations of glycerin exceeding 50% by volume had the potential to ignite when discharged through residential sprinklers. The potential for ignition depended on several factors including the antifreeze solution, ignition source, sprinkler model, sprinkler elevation, discharge pressure, and the location of the sprinkler with respect to the ignition source.

Results of the Scope B testing indicated that concentrations of propylene glycol not exceeding 40% by volume and concentrations of glycerin not exceeding 50% by volume have similar performance to water when compared using the UL 1626 fire control criteria. Both the 40% propylene glycol and 50% glycerin solutions met the UL 1626 fire control criteria and demonstrated similar performance to that of water alone throughout the series of tests.

The results of the research suggested that antifreeze solutions of propylene glycol exceeding 40% and glycerin exceeding 50% by volume were not appropriate for use in home fire sprinkler systems. It was recommended that consideration be given to an appropriate safety factor for concentrations of these antifreeze solutions permitted by future editions of NFPA 13, as well as warnings and limitations outlined in antifreeze product literature.

The report included the following recommendations for further research:

- Investigate antifreeze solutions supplied through non-residential sprinklers.
- Characterize droplet distributions produced by sprinklers.
- Investigate small or medium scale tests for the ignition of liquid sprays.
- Develop a listing standard for antifreeze solutions used in sprinkler systems to encourage the development of alternative solutions.

The first recommendation was identified as particularly important to developing requirements for antifreeze solutions used in non-residential sprinkler systems.

B. Test Plan

The current research was developed to investigate the potential for ignition of antifreeze supplied through non-residential, spray sprinklers. The scope of the project does not include investigating the effectiveness of the antifreeze sprays in controlling a fire condition.

The test plan was similar to Scope A of the Foundation's prior research on residential sprinkler systems. The test configuration consisted of a heptane spray burner positioned below a sprinkler. The operating mechanism was removed from the sprinkler prior to the test and the operating pressure was incrementally increased during each test to investigate a range typically from 20 psi to 150 psi. The basic test configuration is illustrated in Figure 1, below, and is similar to the test configuration used for the prior research on residential sprinklers.

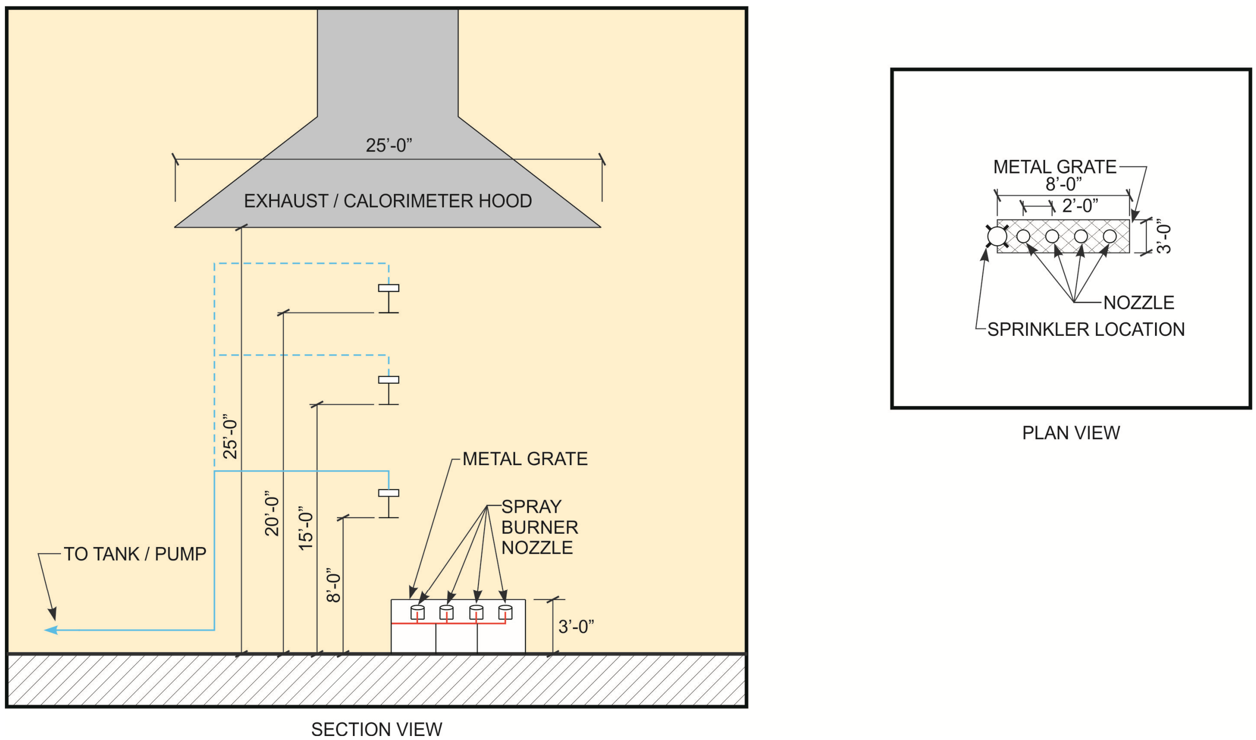

Figure 1. Test Configuration

Prior research suggested that solutions of 50% glycerin and 40% propylene glycol have similar performance in the ignition test configuration. [2] Thus, all tests were conducted with a solution of 50% glycerin by volume based on the results also being applicable to a solution of 40% propylene glycol by volume.

The ignition source used in the tests is intended to provide a conservative representation of the potential fire conditions that a sprinkler system may be designed to control or suppress. The Foundation's prior work investigated a variety of ignition sources and used a nominal ignition source heat release rate of 1.4 MW for the majority of the tests. The ignition source heat release rate was based in part on an analysis of the estimated fire size at sprinkler activation for a residential sprinkler. The analysis was based on the typical ceiling heights in residential occupancies and the response characteristics of residential sprinklers.

Residential sprinklers use a fast-response operating element to achieve relatively quick activation and limit the size of a fire condition. Spray sprinklers are available and have been produced with a variety of operating elements and activation temperatures that may allow for a fire size greater than 1.4 MW to occur prior to sprinkler activation. In addition, spray sprinklers are installed in spaces with ceiling heights greater than those typically found in residential occupancies which may allow for a further increase in fire size prior to sprinkler activation. Thus, this test program investigated the impact of increasing the nominal heat release of the ignition source from 1.4 MW to 3.0 MW. The current testing used same heptane spray burner ignition source that was used for the prior research on residential sprinklers. The heptane spray burner provided a substantial ignition source that was difficult to extinguish.

Tests were conducted with seven (7) commercially available spray sprinklers. The sprinklers included nominal k-factors ranging from 2.8 gpm/psi$^{1/2}$ to 8.0 gpm/psi$^{1/2}$. In addition to standard spray sprinklers, an extended coverage sprinkler was also tested. Four sprinklers with k-factors of 5.6 gpm/psi$^{1/2}$ were tested to investigate the impact of variables other than the nominal k-factor of the sprinkler on the potential for ignition of the spray.

Table 1, below, summarizes the various tests that were conducted.

Test No.	Sprinkler	Height (ft)	Ignition Source HRR (MW)
1	residential k3.1	8	3.0
2	k2.8	8	3.0
3	k4.2	8	3.0
4	k5.6 pendant	8	3.0
5	k5.6 upright	8	3.0
6	k5.6 concealed	8	3.0
7	K5.6 extended coverage	8	3.0
8	k8.0	8	3.0
9	k2.8	20	3.0
10	k4.2	20	3.0
11	k5.6 concealed	20	3.0
12	k8.0	20	3.0
13	k8.0	20	1.4
14	k4.2	20	1.4
15	k8.0	15	3.0

Table 1. Test Matrix

C. Results

The results indicate that the heat release rate of the ignition source can have a substantial impact on the ignition of the antifreeze spray. Figure 2, below, compares the results of tests using a 1.4 MW ignition source with otherwise identical tests using a 3.0 MW ignition source.

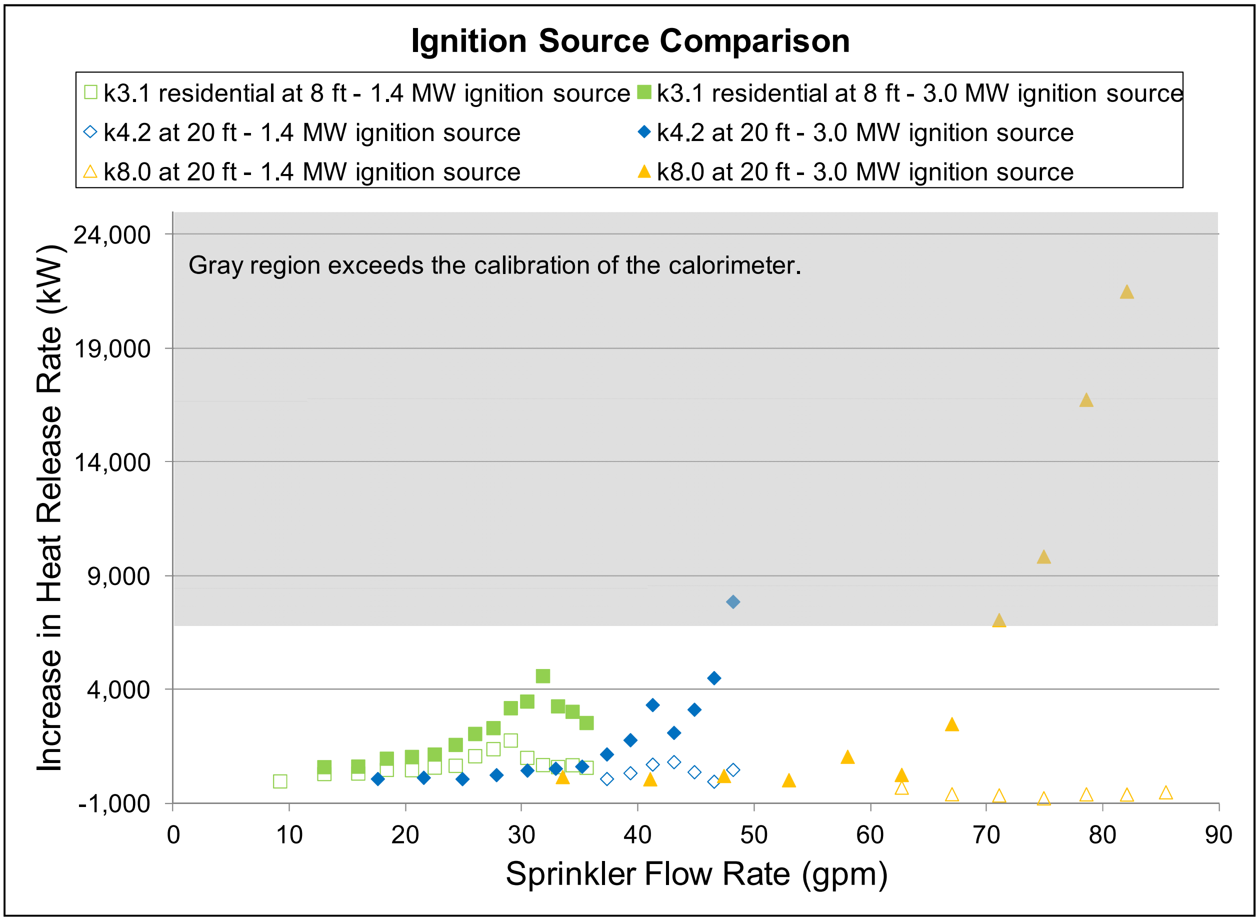

Figure 2. Comparison of increase in heat release rate based on ignition source.

As indicated in Figure 2, above, substantial increases in heat release rate were measured for solutions of 50% glycerin supplied through several sprinklers using the 3.0 MW ignition source. The measured increase in heat release rate is due to ignition of the antifreeze. The increase is heat release rate does not occur or is substantially less with the 1.4 MW ignition source.

Results with the sprinkler positioned at 8 ft above the floor showed a significant variation in the increase in heat release rate depending on the sprinkler and the operating pressure. Results for the 8 ft tests are illustrated in Figure 3, below.

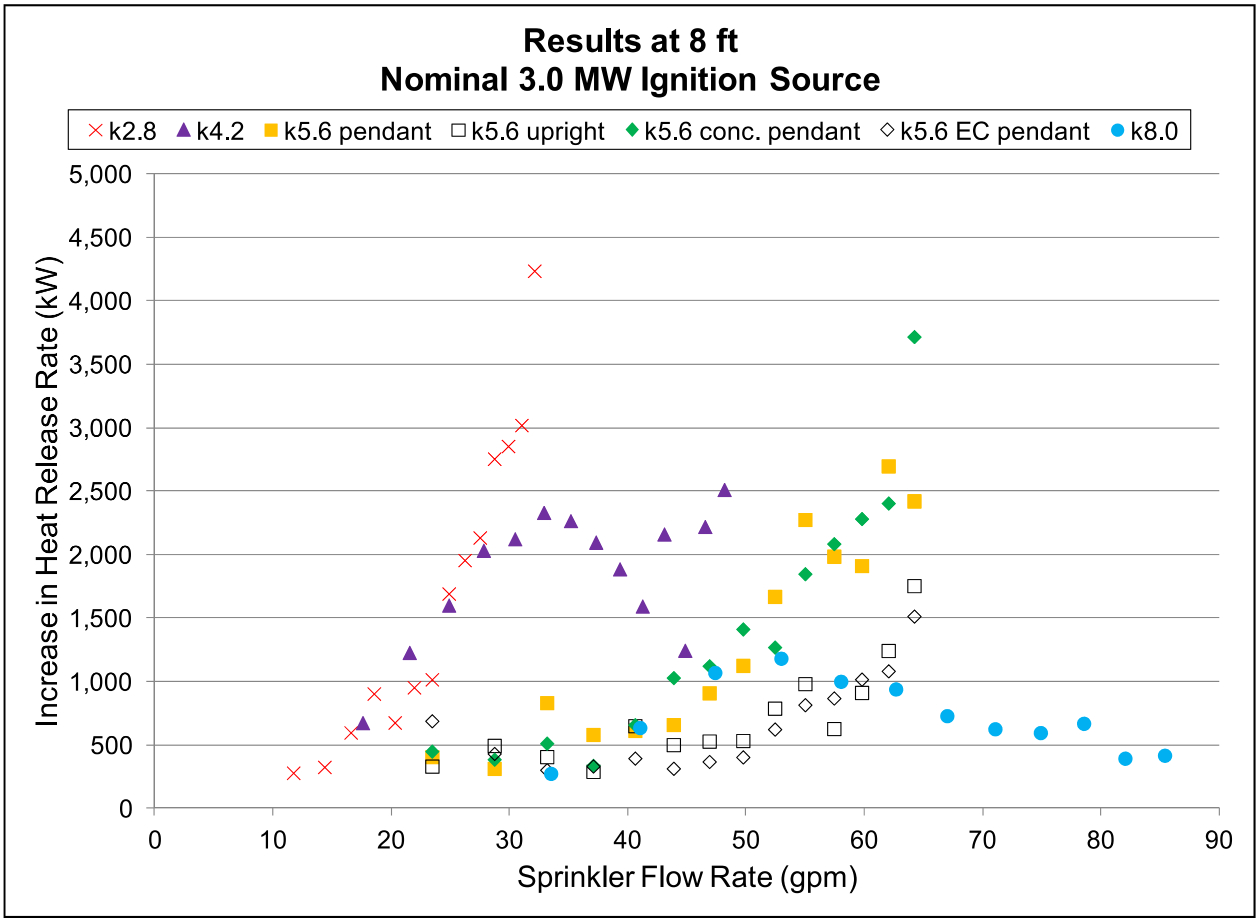

Figure 3. Increase in heat release rate during tests at 8 ft.

Of the tests at 8 ft, the greatest increase in heat release rate occurred with the k2.8 sprinkler where the heat release rate increased by approximately 135% due to ignition of the antifreeze spray. A similar increase in heat release rate was also measured during the test with the k5.6 concealed sprinkler. In contrast, a maximum increase of 40% was measured in the test with the k8.0 sprinkler.

The maximum increase in heat release rate varied from approximately 1,500 kw to more than 3,700 kW in the various tests with k5.6 sprinklers. Thus, factors other than the nominal k-factor of the sprinkler, such as deflector design and configuration, influence the droplet distribution and the potential for ignition of the antifreeze.

Substantial ignition of the antifreeze spray and flames extending away from the ignition source were observed during two of the tests with the sprinkler positioned at 20 ft above the floor. Results for the 20 ft tests are illustrated in Figure 4, below.

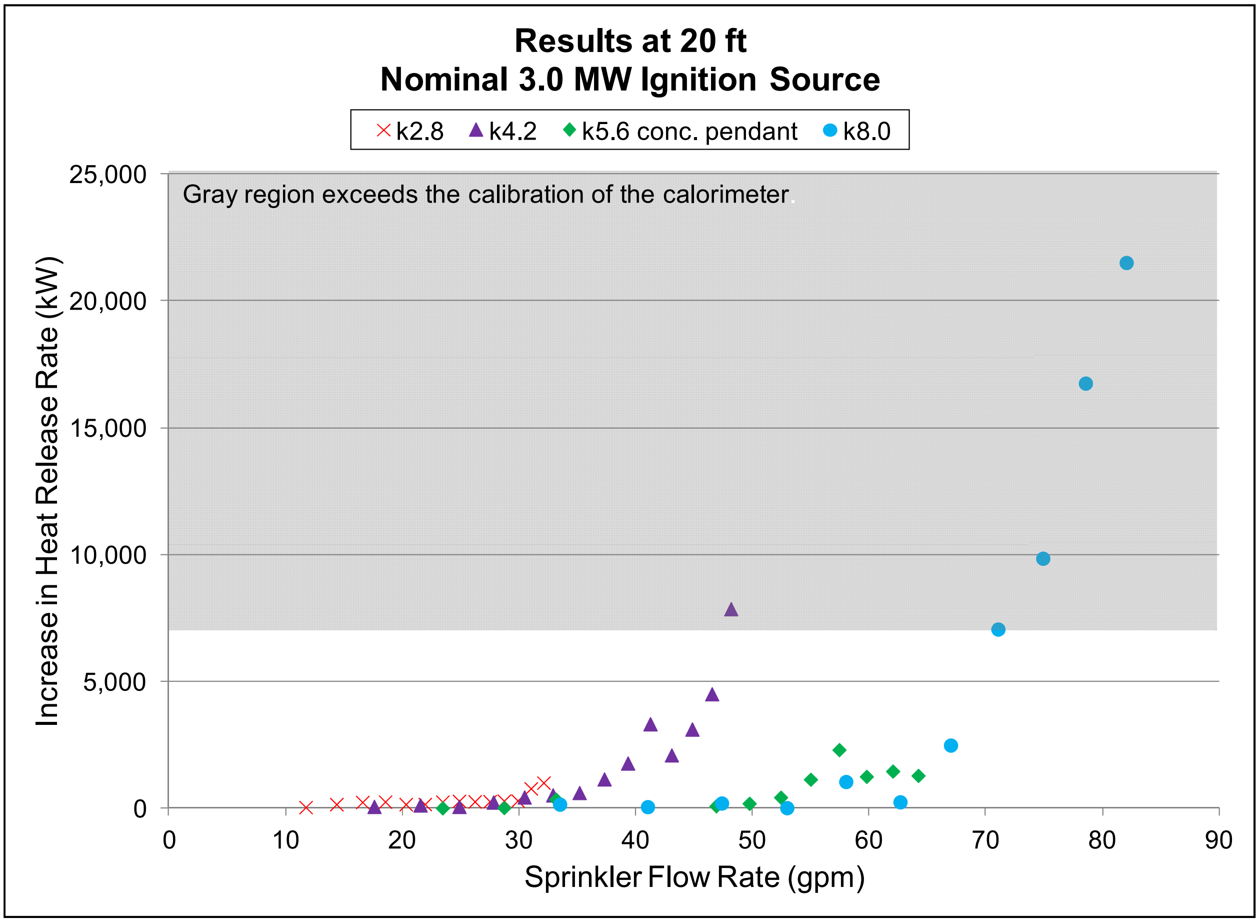

Figure 4. Increase in heat release rate during tests at 20 ft.

In contrast to the results at 8 ft, only a minor increase in heat release rate was measured during the test with the k2.8 sprinkler at 20 ft. However, a substantial ignition of the antifreeze spray and increase in heat release rate occurred during tests with the k4.2 and k8.0 sprinklers at 20 ft. In both tests flames were observed away from the ignition source.

The interaction between the ignition source and the antifreeze spray appears to have a significant role in the potential for ignition of the antifreeze. Because results with the k8.0 sprinkler differed substantially between the test at 8 ft and the test at 20 ft, an additional test was conducted with the k8.0 sprinkler positioned at 15 ft above the floor. The results are illustrated in Figure 5, below.

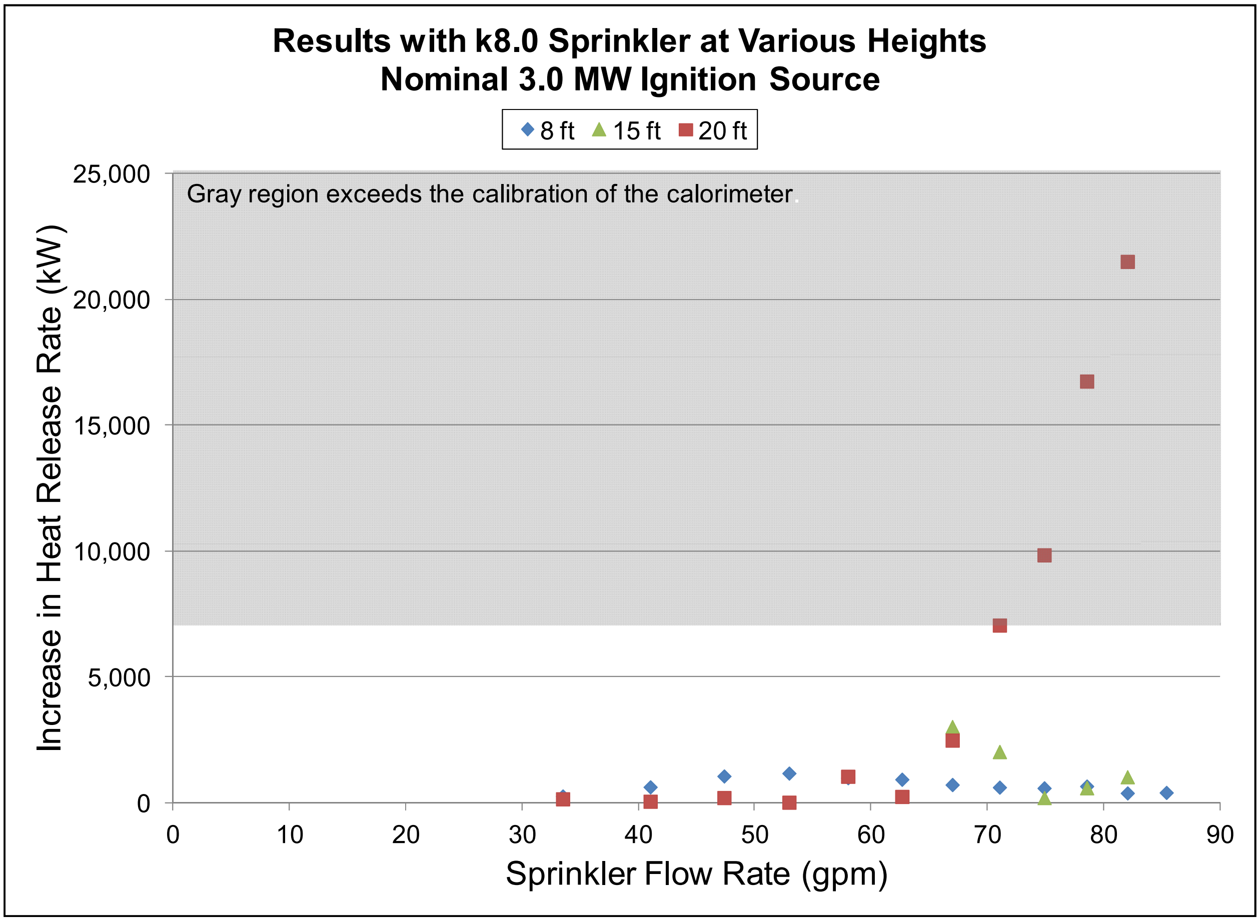

Figure 5. Comparison of increase in heat release rate based on sprinkler height.

The potential for ignition of the antifreeze spray depends not only on the droplet distribution from the sprinklers, but also on the presence of a suitable ignition source. In the test at 8 ft, the spray from the k8.0 sprinkler has significant density and momentum when it reaches the ignition source. The spray has a notable impact on the ignition source as it would be expected to have on many fire conditions.

In contrast, the antifreeze spray from the same sprinkler at 20 ft has significantly less momentum when it reaches the ignition source. The spray appears to have little impact on the ignition source.

The test at 15 ft showed a combination of the two conditions. At the beginning of the test at 15 ft, when the operating pressure was in the range of 80 psi to 90 psi, an increase in heat release rate of more than 100% was measured and flames were observed to extend away from the ignition source. As the operating pressure increased the spray from the sprinkler had significant momentum when it reached the fire and there was little, if any, increase in heat release rate.

The results demonstrate a complicated interaction between the sprinkler spray and the ignition source that appears to influence the potential for ignition of the antifreeze spray.

D. Summary

The Foundation has completed a test program to investigate the potential for ignition of antifreeze solutions of 50% glycerin supplied through spray sprinklers. Based on prior research, similar results would also be expected with solutions of 40% propylene glycol. The current research did not investigate the effectiveness of antifreeze sprays in controlling a fire condition.

The current test program investigated nominal ignition source heat release rates of 1.4 MW and 3.0 MW. The 1.4 MW ignition source is the same ignition source used for the Foundation's prior research on residential sprinklers and was used to provided comparable data between the two test programs. The 3.0 MW ignition source was used to better characterize the fire size at sprinkler activation for certain non-residential fire conditions.

Increasing the ignition source heat release rate was found to significantly increase the ignition of the antifreeze spray in some tests. Results of tests with spray sprinklers and the 1.4 MW ignition source were consistent with the results of the Foundation's prior research program on residential sprinklers using the same 1.4 MW ignition source. The 1.4 MW ignition source was not able to ignite a substantial portion of the antifreeze spray. In contrast, some tests with the 3.0 MW ignition source resulted in an increase in heat release rate of more than 200% with flames extending away from the ignition source.

The test program used seven (7) commercially available spray sprinklers with nominal k-factors ranging from 2.8 gpm/psi$^{1/2}$ to 8.0 gpm/psi$^{1/2}$. The sprinklers were selected to include a range of deflector configurations, which was found to impact the potential for ignition of the antifreeze spray. The nominal k-factor of the sprinkler was not found to determine the potential for ignition of the antifreeze spray. Further testing is anticipated as part of this project to characterize the droplet distribution from several of the sprinklers included in this test program.

In tests with the sprinklers positioned at 8 ft above the floor, a maximum increase in heat release rate of more than 4,000 kW or approximately 135% was measured with the k2.8 sprinkler. A similar increase in heat release rate was measured with a k5.6 concealed sprinkler. The maximum increase in heat release rate varied by more than a factor of two between the different k5.6 sprinklers tested. Antifreeze solutions supplied through other sprinklers showed varying increases in heat release rate, with the k8.0 sprinkler having the lowest maximum increase in heat release rate of approximately 40%.

In contrast, results at 20 ft showed an increase in heat release rate of more than 200% for both the k4.2 and the k8.0 sprinklers at certain operating pressures. Ignition of the antifreeze spray away from the ignition source was observed in tests with both the k4.2 and k8.0 sprinkler at 20 ft. An additional test was conducted with the k8.0 sprinkler at 15 ft that showed that the potential for ignition of the spray can depend on a complex interaction between the spray distribution from the sprinkler and the ignition source.

The final report on this test program is anticipated to include additional analysis of several of the factors that affect the potential for ignition of the antifreeze spray. In addition to the antifreeze solution, these factors include:

- the ignition source (fuel package);
- the configuration of the sprinkler with respect to the ignition source; and
- the sprinkler model and operating pressure along with the resulting droplet distribution.

The results of this test program indicate that limitations should be considered on the use of 50% glycerin or 40% propylene glycol antifreeze solutions in non-residential sprinkler systems. Ignition of substantial portions of the antifreeze spray was observed in several of the tested configurations. In addition, testing has not been conducted to investigate the effectiveness of antifreeze solutions in controlling non-residential fire conditions. The additional analysis and droplet distribution testing that will be documented in the final report may provide information that could assist in developing future requirements for the use of glycerin and propylene glycol antifreeze solutions in non-residential sprinkler systems.

E. References

[1] Code Consultants, Inc., "Literature Review and Research Plan, Antifreeze Solutions in Home Fire Sprinkler Systems," Fire Protection Research Foundation, 2010.

[2] Code Consultants, Inc., "Phase II Research: Antifreeze Solutions in Home Fire Sprinkler Systems," Fire Protection Research Foundation, 2010.