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Fire Extinguishing Performance of the ICAF System with Synchronous Operation of Sprinklers

Research Report # IRC-RR-237

Date of Issue: August 2007

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Published by
Institute for Research in Construction
National Research Council Canada
Ottawa, Canada
K1A 0R6

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Abstract

Many questions have been brought forth concerning the ability to have sprinklers of various densities run in synchronous operation with the Compressed-Air-Foam (CAF) technology. Fixed pipe CAF systems were developed by the National Research Council of Canada (NRC), incorporating air, water, and foam concentrate in an innovative injection method creating a robust substance with very small bubbles. This new technology has demonstrated very impressive fire suppression performances through full scale fire testing. However, the CAF performances have never been tested while sprinklers are operating simultaneously.

Standard sprinklers are used in most applications in various industries for building protection. However, in many cases water alone is not adequate and simple control is not enough. In these cases another extinguishing system is needed which provides additional fire protection. A CAF system can respond to these needs for a particular risk. If a CAF system is installed in a room where there already exists a sprinkler system then the performance of both systems running simultaneously needs to be evaluated to make sure that the sprinklers do not interfere with the performance of the CAF system.

This series demonstrates that the two systems can in fact operate together without serious performance degradation in both extinguishment time and burn-back protection. This is true for a wide range of sprinkler densities up to 24.5 L/min/ m^2 (0.6 gpm/sq.ft).

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1.0 Introduction

Many questions have been brought forth concerning the ability to have sprinklers of various densities run in synchronous operation with the Compressed-Air-Foam (CAF) technology. Fixed pipe CAF systems were developed by the National Research Council of Canada (NRC), incorporating air, water, and foam concentrate in an innovative injection method creating a robust substance with very small bubbles. This new technology has demonstrated very impressive fire suppression performances through full scale fire testing. However, the CAF performances have never been tested while sprinklers are operating simultaneously.

Standard sprinklers are used in most applications in various industries for building protection. However, in many cases water alone is not adequate and simple control is not enough. In these cases another extinguishing system is needed which provides additional fire protection. A CAF system can respond to these needs for a particular risk. If a CAF system is installed in a room where there already exists a sprinkler system then the performance of both systems running simultaneously needs to be evaluated to make sure that the sprinklers do not interfere with the performance of the CAF system. A series of fire tests were conducted to address the needs.

Another objective during this test series was to evaluate the CAF performance with respect to the new Factory Mutual (FM) Foam standard 5130 which requires 5 minutes of sprinkler discharge at a density of 10.2 L/min/ m^2 (0.25 gpm/sq.ft.) at the completion of the 5 minute foam discharge.

In this test series, the performance of the CAF technology was tested by having a sprinkler grid over the CAF grid. Different densities of sprinklers, locations and fuel types were used to evaluate the performance of the CAF system.

2.0 Experimental Set-Up and Procedure

The experimental procedure used in this test series is similar to the new FM Foam Standard 5130. However, the majority of the tests were done in more severe conditions with higher water densities and various piping configurations.

2.1 Piping System and Nozzles

The piping network for this test series consists of a 3m x 3m (10' x 10') sprinkler grid with an option to change the location of the heads to a 90° position (see Figure 1). This grid is independent of the CAF grid. The sprinkler grid is supplied by a 7.6cm (3") riser and a 6.35 cm (2 ½") hose line. The grid is connected to a Rosemount magnetic flow meter which has a two valve system on the output side. One valve was to preset the flow and the other valve was to turn the flow on or off. For this test series, two different types of

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sprinklers were used. For water densities of10.2 L/min/ m^2 (0.25 gpm/sq.ft) and lower, a Viking Upright Model, VK100 K= 5.6, was used. For densities higher than 10.2 L/min/ m^2 (0.25 gpm/ sq.ft), a Viking Upright Model, VK530 K= 11.2, was used. The exception was Test 2 (with a water density of 16.3 L/min/ m^2 (0.4 gpm/sq.ft) where VK100 K= 5.6 was used. The position of the sprinkler heads could be changed from being directly above the CAF heads to being 90° in reference to the CAF system. The height of the sprinkler heads were 11.75 m (38.5 ft) from the floor.

For the CAF grid the small spinner nozzles TAR 225C were used to distribute the CAF uniformly. There were two grid dimensions used for this test series, the standard 3.75m x 3.75m (12.3' x 12.3') which gives a density of 1.63 L/min/ m^2 (0.04 gpm/ sq.ft.) and a smaller grid spacing of 3m x3m (10' x 10') which produces a density of 2.45 L/min/ m^2 (0.06 gpm/ sq.ft). The CAF nozzles were at 11m (36 ft) from the floor. The CAF system used is a single 3.8 cm (1 ½") mixing chamber with multiple foam tanks depending on the quantity and type of foam concentrate used. The system had its bank of cylinders and a controller for automatic shut-off after the timer expired.

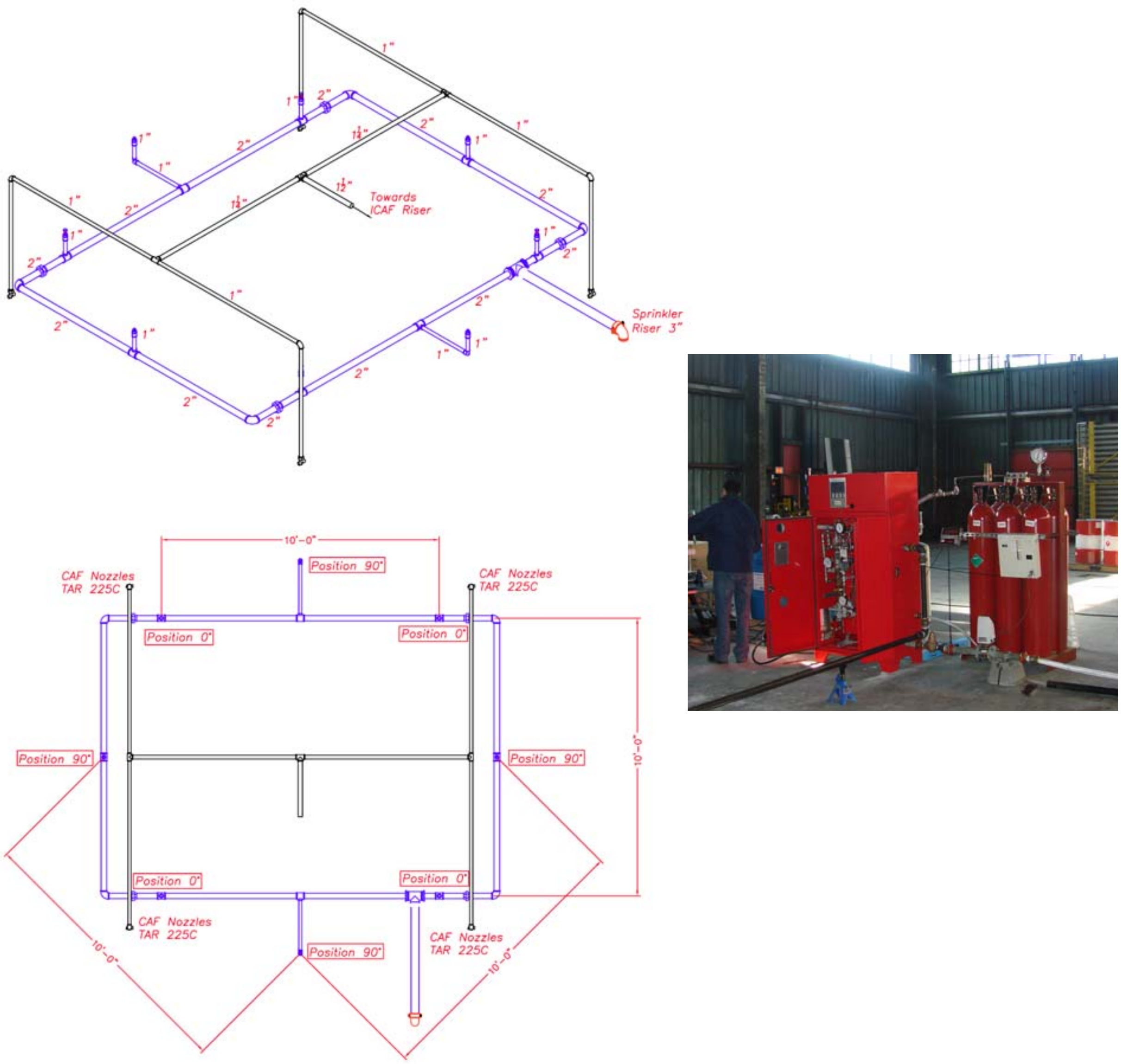

Figure 1. CAF and Sprinkler Piping Layout and CAF Generator

2.2 Test Fire

There were two test fires for this series. There was a heptane pool fire with commercial grade heptane fuel in a fire test pan that was placed on the floor, centered below the piping grid of the sprinklers and the rotary CAF nozzles. There was also an acetone pool fire 99.5% pure in a fire test pan located at the same place as the heptane fire. The test pan is the one described in the UL 162 and FM 5130 standards. The pan was square, straight-sided, with an area of 4.65 m^2 (50 square feet), and made of 6.4 mm (¼ inch) thick steel plate (Figure 2).

Figure 2. Test Pan

For the heptane fire, 205 litres (54 gal) of heptane was added to the pan. The fuel layer was floated on no less than 25.4 mm of water to produce a lip height not less than 203 mm (8 in). The acetone fire used 205 litres (54 gal) of fuel with no water added to the pan.

2.3 Foam Concentrates

There were two different types of foam concentrates used in this test series. Class B foam concentrate was an Aqueous-Film-Forming-Foam AFFF, manufactured by National Foam used at either 2%, 3% or 6% depending on the test configuration. Ansulite Low Viscosity Alcohol Resistant foam concentrate AFFF-AR manufactured by Ansul was also used during the test series at 6% concentration.

2.4 Test Procedure

Two test procedures are performed for this test series, with different timing.

2.4a Procedure #1 Following the FM 5130 Protocol:

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For the FM 5130 test sequence, the fuel in the test pan is ignited and the fire is allowed to burn freely for a 15 second pre-burn. At the end of the 15 second pre-burn the CAF application starts and continues for 5 minutes until automatic shut-down. After the CAF discharge is complete the sprinklers are activated at 10.2 L/min/ m^2 (0.25 gpm/ sqft) and left on for an additional five minutes. After the 5 minutes of water application 2 torch tests are conducted. One immediately after the sprinklers are turned off and again 5 minutes later. This consists of a lighted torch passing approximately 25.4 mm (1 in) above the entire foam blanket, in an attempt to re-ignite the fuel. Each torch test lasts for a period of not less than 1 minute (Figure 3).

Figure 3. Torch Test

After passing both of the torch tests, a burn-back test is conducted. A 0.3m (1ft) diameter stovepipe is placed approximately 0.76m (2.5 ft) from each of two adjacent sides of the test pan, in the corner where the flame extinguished last, and placed in such a manner that the foam blanket is not disturbed. The portion of the foam blanket that is enclosed by the stovepipe is removed (Figure 4), and the fuel inside the stovepipe is ignited and allowed to burn for 1 minute.

Figure 4. Burn back preparation

The stovepipe is then slowly removed from the pan while the fuel continues to burn (Figure 5).

Figure 5. Burn-back starts

After the stovepipe is removed the time for the flame to spread through the foam blanket over an area larger than 0.9 m^2 (10 sq.ft.) is recorded. In order to pass the burn back portion of the test this time must be greater than 5 minutes or self-extinguish due to the foam flowing in from the edges.

2.4b Procedure #2 Modified FM 5130 Protocol:

In the tests not following the FM 5130 test sequence, the fuel in the test pan is ignited and the fire is allowed to burn freely for a 15 second pre-burn. At the end of the 15 second pre-burn the CAF and sprinklers are activated simultaneously and continue for 5 minutes until the CAF automatically shuts off. After the CAF discharge is stopped the sprinklers are left on for an additional five minutes for a total of 10 minutes of water application. Depending on the density of water applied a 5cm (2") ball valve at the bottom of the pan is opened when the level approaches the top of the pan. This is to make sure the pan will not overflow and only the water at the bottom of the pan is removed.

Once the sprinklers are turned off the valve is immediately closed and a torch test is conducted by passing a torch approximately 25.4 mm (1 in) above the entire foam blanket, including corners, in an attempt to re-ignite the fuel. Upon passing this torch test the sprinklers are re-activated for another 5 minutes and then the torch test is performed once again. If the torch test is successful then more water is added for another five minutes and the cycle repeated until the foam blanket is deteriorated and the torch test fails.

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3.0 Results and Discussion

The results of this test series are summarized in Table 1. Tests 13 to 20 were conducted in the presence of FM representatives. Tests 1, 13 and 20 where performed to demonstrate that the CAF technology can pass the new FM 5130 foam standard (Test 1 had sprinklers operating during the CAF discharge until extinguishment and reactivated for 5 minutes after CAF discharge ended). Extinguishment time was the same as previous CAF tests in the same conditions and although adding a subsequent discharge of water for five minutes both torch tests were passed as well as the burn-back. The time for the burn back in Tests 1 and 13 were slightly affected but well in excess of the allowed time in the standard of 5 minutes. In Test 20 there was no burn back because the fire self-extinguished.

In Tests 2 to 7 a sprinkler density of 16.3 L/min/ m^2 (0.4 gpm/sq.ft.) was used to evaluate the effect of sprinkler head location in relation to the CAF rotary nozzles and the effect of different sprinkler K factors. Two different CAF design configuration were also evaluated. Results from Tests 2 and 3 show that the different K factors for the sprinklers do not affect the performances of the CAF when in operation together. The extinguishment times are only seconds apart. The effect of the sprinkler position is seen in Test 3 and 4. When the sprinklers are in position 0° (just above the CAF TAR 225C spinner nozzles) the extinguishment time is slightly better than when the sprinklers are in the 90° position in reference to the CAF. There is a 17 second time difference however both tests are under 2 minutes which is well below the 5 minutes allowed during this test protocol. Tests 4 and 6 as well as Tests 8 and 9 demonstrate that the design of the CAF system either with sprinklers at 16.3 or 24.5 L/min/ m^2 (0.4 or 0.6 gpm/sq.ft.) can be 3.73 m x 3.73 m (12.3' x 12.3') at a concentration of 6% or 3 m x 3 m (10' x 10') at a concentration of 3%. The fire extinguishment results are similar for both sets and well under the five minutes allowed.

Tests 11, 12 and 21 were conducted to demonstrate the effectiveness of CAF alone and sprinklers alone. With the alcohol resistant foam concentrate on a heptane fire the CAF performed very well and extinguished the fire in 39 seconds. Sprinklers alone at a density of 24.5 L/min/ m^2 (0.6 gpm/sq.ft.) on a heptane fire was not able to extinguish the fire. The fire with the sprinklers was knocked down slightly but there was still a good size fire burning after the allowed time for the test (Figure 6). In Test 21 the sprinklers at 24.5 L/min/ m^2 (0.6 gpm/sq.ft.) were used on an acetone fire. The fire was knocked down but was not extinguished in the 5 minutes. Water was added for 11 minutes 30 seconds in total and the fire was not extinguished. When the system was finally turned off there were small blue flames left burning on the surface that were eventually extinguished by activating the CAF system at 21 minutes.

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Sprinkler activation

@ 1 minute

@ 2 minutes

@ 3 minutes

@ 4 minutes

Figure 6. Test 12 Heptane with 24.5 L/min/ m^2 (0.6 gpm/ sq.ft) sprinkler suppression

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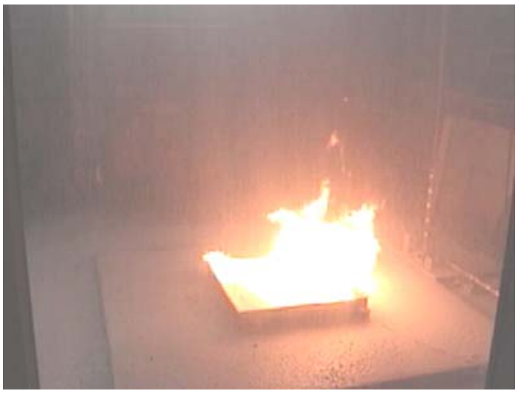
In Tests 14 to 16 the effectiveness of the CAF with sprinklers in synchronous operation was demonstrated through a wide range of sprinkler densities on heptane fires. All three tests had good extinguishment times (Figures 7 and 8) and they all passed the first torch test. In order to test the resiliency and strength of the foam blanket additional water was added for 5 minutes and the torch test was performed again for Tests 15 and 16. In Test 15 another 5 minutes of water was applied and the torch test was performed once again and it passed. A third extra sprinkler cycle was attempted but after two minutes a hole started to appear in the foam blanket. This represents 17 minutes of sprinkler application at 16.3 L/min/ m^2 (0.4 gpm/sq ft) on the CAF blanket before the surface of the fuel was exposed and a total of 22 minutes of sprinkler application from the initial CAF and sprinkler activation.

Dual System activation

@ 30 s



@ 1 minute

@ 1 minute: 40 s

Figure 7. Test 15; CAF and 16.3 L/min/ m^2 (0.4 gpm/sq.ft) Sprinkler Suppression

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Dual System Activation

@ 30s

@ 1 minute

@ 1 minute: 30 s

@ 2 minutes

@ 2 minute: 48 s

Figure 8. Test 16; CAF and 24.5 L/min/ m^2 (0.6 gpm/sq.ft) Sprinkler Suppression

In Test 16 the sprinkler density was increased to 24.5 L/min/ m^2 (0.6 gpm/sq ft) and the blanket opened a hole after the second extra sprinkler cycle was initiated. The cycle was terminated and the open hole was ignited. The blanket was still substantial enough after 10 minutes of 24.5 L/min/ m^2 (0.6 gpm/sq ft) sprinkler application to provide over 4 minutes burn back protection before the fire involved 25% of the surface.

In Tests 17 to 19 the effectiveness of the CAF with sprinklers in synchronous operation was demonstrated on polar solvent fuels (in this case acetone). Tests 17 and 18 performed very well with the sprinklers running simultaneously. After the CAF discharge the high density of water created some agitation on the surface which helped create more expansion to the CAF blanket. In both cases the extinguishment performances were very good and there was no burn back due to self extinguishment. For Test 19 the fire was not extinguished in the allowed time for the standard. There was significant knockdown of the fire but there were small flames left on the sides of the pan after the CAF and sprinkler discharge. There was just enough water to hinder the CAF performance and not enough to help cool down the hot edges of the pan or significantly dilute the polar solvent fuel.

4.0 Conclusions

4.1 FM 5130 Protocol Tests

The CAF system had no problem adapting to the new FM 5130 standard from the modified UL162 standard that was previously used. The main difference between these 2 protocols was the addition of the 5 minutes of 10.2 L/min/ m^2 (0.25 gpm/sq ft) sprinkler application after the CAF discharge was complete. The extinguishment portion is the same and the burn-back protection approached or exceeded 4 times the allowable 5 minutes.

The procedure for the polar solvent fuels did not change since the addition of water after the CAF extinguishment would only dilute the fuel and it was demonstrated that the blanket was not deteriorated by the addition of 5 minutes of 10.2 L/min/ m^2 (0.25 gpm/sq ft) sprinkler application.

4.2 ModifiedFM 5130 Protocol Tests

This portion of the test series was conducted to demonstrate that CAF and sprinklers can operate synchronously and still extinguish both hydrocarbon (heptane) and polar solvent fuel fires (acetone). Furthermore the addition of at least 5 minutes of extra sprinkler application after the CAF discharge ends does not deteriorate the foam blanket to the point where it does not provide excellent burn-back protection. This was the case in all tests with the exception of Test 19 where at the end of the 5 minute discharge period, for the CAF and sprinkler combination, small candle flames were left burning on the edges. The addition of a low sprinkler density offered little in the way of cooling to the pan and dilution of the fuel but did manage to weaken the CAF blanket by disturbing and agitating the surface.

The CAF and sprinkler combination also demonstrated that a small amount of concentrate when used to form CAF is very effective compared to the equivalent foam-water application. The concentrate used in these tests represents only 0.3% to 0.5% of the total water flow rate. Foam-water systems are ineffective at these concentrations while the CAF system performance was only marginally affected.

4.3 Sprinkler Tests

Two sprinkler tests were also conducted using the high 24.5 L/min/ m^2 (0.6 gpm/sq ft) application density on both the heptane and acetone fires. This demonstrated that even high sprinkler densities have very little effect on low flash point hydrocarbon fires and can only extinguish polar solvent fuels through large dilution rates in excess of 85%. Test 21 applied 24.5 L/min/ m^2 (0.6 gpm/sq ft) to the acetone fire for over 11 minutes until the pan was full and did not extinguish the fire. It continued to burn and at 21 minutes had to be extinguished with CAF. This represents a dilution of 85%. High sprinkler application rates could be used for shallow spills of polar solvent fires but are not suitable for control or extinguishment of volatile hydrocarbon or deep pools of polar solvent fuel fires.

5.0 Acknowledgements

The author wishes to thank Jonathan Roger, Jean-Pierre Asselin and the staff of FireFlex Systems Inc., Michael Ryan and the staff of the NRC-IRC Fire Research Program for their assistance and contributions to this test series.

6.0 Bibliography

1. FM Global ; Approval Standard for Foam Extinguishing Systems, Class Number 5130, April 2007
2. CAN/ULC-S560-98 Standard for Category 3 Aqueous Film-Forming Foam (AFFF) Liquid Concentrates.
3. UL 162, Standard for Foam Equipment and Liquid Concentrates

Table 1: Test Results:

Test	Sprinklers (10' x10')		ICAF				Sprinkler Position vs. CAF Nozzles	Fuel	Extinguish Time (min: sec)	Extra Water after CAF discharge and passing torch test (min)	Burn Back (min:sec)	Remarks
	Density (gpm/ft^2)	K (factor)	Spacing	Density (gpm/ft^2)	Foam Type	Foam Conc.						
1	0.25	5.6	12.3' x 12.3'	0.04	AFFF	2%	0°	Heptane	1:56	5	19:30	Note 1
2	0.4	5.6	12.3' x 12.3'	0.04	AFFF	6%	0°	Heptane	1:24	N/A	N/A	Note 4
3	0.4	11.2	12.3' x 12.3'	0.04	AFFF	6%	0°	Heptane	1:21	5	26:00	Note 1
4	0.4	11.2	12.3' x 12.3'	0.04	AFFF	6%	90°	Heptane	1:38	N/A	N/A	Note 4
5	0.4	11.2	10' x 10'	0.06	AFFF	2%	90°	Heptane	2:33	N/A	N/A	Note 4
6	0.4	11.2	10' x 10'	0.06	AFFF	3%	90°	Heptane	1:28	5	Self Ext.	Note 2
7	0.4	11.2	10' x 10'	0.06	AFFF	3%	0°	Heptane	1:11	5	Self Ext.	Note 2
8	0.6	11.2	12.3' x 12.3'	0.04	AFFF	6%	90°	Heptane	2:00	N/A	N/A	Note4
9	0.6	11.2	10' x 10'	0.06	AFFF	3%	90°	Heptane	2:27	5	Long	Note 2
10	0.4	11.2	10' x 10'	0.06	AR	6%	90°	Acetone	3:35	N/A	Long	Note 3
11	N/A	N/A	12.3' x 12.3'	0.04	AR	6%	N/A	Heptane	0:39	N/A	N/A	CAF Alone
12	0.6	11.2	N/A	N/A	N/A	N/A	N/A	Heptane	Not Ext.	N/A	N/A	Spk Alone
13	0.25	5.6	12.3' x 12.3'	0.04	AFFF	2%	90°	Heptane	0:56	5	26:00	Note 1
14	0.2	5.6	12.3' x 12.3'	0.04	AFFF	2%	90°	Heptane	1:59	5	N/A	Note 2
15	0.4	11.2	12.3' x 12.3'	0.04	AFFF	6%	90°	Heptane	1:25	15	N/A	Note 2
16	0.6	11.2	12.3' x 12.3'	0.04	AFFF	6%	90°	Heptane	2:28	10	N/A	Note 2
17	0.4	11.2	10' x 10'	0.06	AR	6%	90°	Acetone	3:31	10	N/A	Note 2
18	0.6	11.2	10' x 10'	0.06	AR	6%	90°	Acetone	2:22	5	N/A	Note 2
19	0.2	5.6	10' x 10'	0.06	AR	6%	90°	Acetone	Not Ext (See Note 5)	N/A	N/A	Note 2
20	0.25	5.6	10' x 10'	0.06	AR	6%	90°	Heptane	0:36	5	Sel Ext	Note 1
21	0.6	11.2	N/A	N/A	N/A	N/A	N/A	Acetone	Not Ext	N/A	N/A	Spk Alone

Note 1: According to FM Foam Standard 5130
Note 2: Sprinklers were running for 10 minutes from system activation at 15 seconds
Note 3: Sprinklers were running for 5 minutes from system activation
Note 4: Fire test conducted with sprinklers and CAF running simultaneously only until extinguishment
Note 5: The fire was knocked down only small flames left on the edge of the pan.

AFFF = National Aer-O-Lite 3%
AR = Ansulite 3 x3 LV

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