Enhanced Fire Extinguisher Project
Class C FireIce Testing - Series 2

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EXECUTIVE SUMMARY

This test series expands on results obtained during initial testing that was performed on a 2.5 gallon Amerex portable extinguisher filled with FireIce and pressurized to approximately 100 psi. Modifications were made to the extinguisher assembly to improve the performance during class C testing. The testing was based on UL 711, *Rating and Fire Testing of Fire Extinguishers*, specifically; the testing outlined in section 9, *performance of Class C extinguishers*.

Variables during this test series were limited to the distance between the extinguisher and the electrified target, the nozzle used, and the concentration of FireIce used. The FireIce was premixed the day before using de-ionized water. The goal was to determine if the extinguisher and agent combination could be safely used for class C fires. The testing showed that the current extinguisher configuration was comparable to a UL class C listed extinguisher and showed leakage of less than 0.9 mA at 20 inches.

In addition to the manual fire extinguisher testing, a scaled up Class C test setup was conducted for testing the induction system on a hose line for manual fire fighter operations. The leakage back to the nozzle of a hose line was measured for both water and FireIce inducted into the line. An increase in the leakage was seen when FireIce is used, however the increase was negligible. The product is safe for use at the prescribed 25ft standoff distance currently used by the Fire Department of New York (FDNY) fire fighters when combating an electrified source.

Class C testing of both the 2.5 gallon extinguisher assembly and the FireIce hose stream induction method showed that the FireIce agent can be used safely using current FDNY and conEd safety practices.

For the extinguisher assembly, the most conservative minimum work distance found was set by OSHA and was 3 ft. 4 in for 100kV. For 100 kV a distance of 3 ft. 4 in. (however a distance of 5 ft. is recommended), will provide a safe working distance for the FireIce extinguisher assuming the following:

- Distilled water is used for mixing the FireIce,
- A concentration of 90 grams per 2.5 gallons is used,
- The mist nozzle supplying a 45 degree cone spray is used, and
- The extinguisher is properly pressurized to 100 psi

Under the above conditions the extinguisher passed the UL 711 class C test criteria at 20 inches. Based on a passing result at 20 inches a standoff safe working distance of 5 ft. shall be utilized for Class C fires involving circuits of 100 kV or less.

Operation of the manual fire extinguisher on circuits above the 100 kV threshold have not been validated for safe standoff distances. The 2.5 gallon manual fire extinguisher shall not be used on Class C fires involving circuits above 100 kV without further testing for validation and safe practices.

For the hose stream induction method, a criterion of 25 ft. is established as a safe attack distance for FDNY personal. The FireIce maintained a leakage below the 0.9 mA threshold set by conEd at 15 ft. for 11,000 volts and at 20 ft. for 30,000 volts. Based on these results the application of Fire Ice is safe at a distance of 25 ft. on Class C Fires which do not exceed 30,000 volts. The results indicate that for a manhole fire where the maximum expected line to ground voltage is 11,000 the FireIce can be used safely following the current FDNY practices.

It should be noted that the 25 ft. limit is a critical distance and shall not be impeded under any conditions while applying the FireIce agent. It is recommended a safe area of protection be established at this 25 ft. minimum prior to setting up any manual fire fighting operations to attack a Class C fire.

1.0 BACKGROUND

Electrical fires pose an increased danger due not only to the heat and products of combustion produced from a typical fire but the potential for electrocution due to leakage back to the user. For this reason UL classifies extinguishing agents not only by the fires fuel source and size but if the product can be used for electrical fires, known as class C fires. UL Class C fire testing does not test performance on electrical fires, only the conductivity of the agent. Section 5.5 of UL 711 states;

"There is no numerical component for class C ratings of extinguishers, as only the electrical conducting characteristics of the agent when being discharged are significant, and no effort is made to indicate the extinguishing potential for fires that involve electrical equipment."

This presents a significant issue to fire fighting personnel as they may be under the impression that an agent listed for class C fires is capable of extinguishing class C fires. The reality of the situation is that the agent has only demonstrated its ability to be non conductive. An agent capable of extinguishing a class C fire on the other hand may not be able to pass the high standard of non conductivity established by the UL 711 standard. The class C rating in UL711 also only applies to extinguishers and does not address firefighter operations or other methods of applying the agent.

The UL 711 test configuration results in a pressurized extinguisher being mounted 10 inches from a charged target measuring 12 in. by 12 in. The target is bent at 90 degrees and charged with 100 kV. The extinguisher is discharged onto the target and a leakage of no greater than 1 mA can be measured between the tip of the extinguisher nozzle or horn and the target. In addition to the performance test the agent itself cannot have a measured conductance of more than 1 micro Siemen per centimeter.

A leakage of 0.9 mA (900 micro amps) is the threshold set by Consolidated Edison (conEd) standards. The minimum current a human can feel depends on the current type (AC or DC) and frequency. A person may be able to feel 1 mA of AC at 60 Hz but no pain or detrimental effect would occur. At around 10 mA, AC current passing through the arm of a 68 kg (150 lb) human can cause muscle contractions; the human would be unable to voluntarily control their muscles. This is known as the "let go threshold" and is a criterion for shock hazard in electrical regulations. The current may, if it is high enough, cause tissue damage or fibrillation which leads to cardiac arrest. A current of more than 30 mA of AC can cause fibrillation. It is due to the possibility of electrocution that conEd uses a safe working distance of 4'7" for qualified workers and 6'8" for unqualified workers. OSHA also sets minimum working distances and minimum clear hot stick distances. Below is text and table taken from OSHA regulation.

1926.950(c)(2)(i) The minimum working distance and minimum clear hot stick distances stated in Table 1 shall not be violated. The minimum clear hot stick distance is that for the use of live-line tools held by linemen when performing live-line work.

1926.950(c)(1) No employee shall be permitted to approach or take any conductive object without an approved insulating handle closer to exposed energized parts than shown in Table V-1, unless they meet 950(c)(1)(i);(ii);(iii).

1926.550(a)(15)(ii) For lines rated over 50 kV., minimum clearance between the lines and any part of the crane or load shall be 10 feet plus 0.4 inch for each 1 kV. over 50 kV., or twice the length of the line insulator, but never less than 10 feet.

Table 1 - ALTERNATING CURRENT - MINIMUM DISTANCES

Voltage range (phase to phase) – kilovolt	Minimum working and clear hot stick distance
2.1 to 15	2 ft. 0 in.
15.1 to 35	2 ft. 4 in.
35.1 to 46	2 ft. 6 in.
46.1 to 72.5	3 ft. 0 in.
72.6 to 121	3 ft. 4 in.
138 to 145	3ft. 6 in.
161 to 169	3ft. 8 in.
230 to 242	5ft. 0 in.
345 to 362	7ft. 0 in.*
500 to 552	11ft. 0 in.*
700 to 765	15ft. 0 in. *

* For 345-362 kv., 500-552 kv., and 700-765 kv., minimum clear hot stick distance may be reduced provided that such distances are not less than the shortest distance between the energized part and the grounded surface.

The minimum safe work distances set by OSHA and conEd demonstrate that the UL 711 test is overly conservative. When you consider that a worker should never be 10 in from 100kV, using an extinguisher at that distance seems irrational. Irrelevant of possessing an extinguisher or not the personnel could not operate within the 100kV target at the 10 in distance established by the UL 711 standard.

The goal of this test series and paper was to establish and document the leakage back into the FireIce extinguisher and hose line while looking at the variables of voltage, distance between source and target, and the concentration ratio of FireIce to water used in the extinguisher. Using conEd and FDNY safety practices it can be determined the leakage measured allows for safe usage by conEd employees and NYC firefighters.

2.0 TESTING SETUP

2.1 UL 711 Testing

Testing was conducted to comply with UL 711, Figure 1. The extinguisher was mounted to an insulated platform and operated by remote control, Figure 2. The extinguisher was operated by remote control that initiated a tubular high speed linear actuator with a stroke size of 6 inches and a force of 33 lbs moving at 3.15 inch/sec. A 12 in by 12 in target bent at 90 degrees was constructed to receive the discharge from the extinguisher, Figure 3. The target plate was connected to the high side of the transformer while the extinguisher is connected to the ground side of the test circuit. The transformer was energized while the leakage to the extinguisher nozzle was measured. An AC test system was used capable of generating 120kV phase to ground – 200mA output, Figure 4. The leakage was measured using a multimeter.

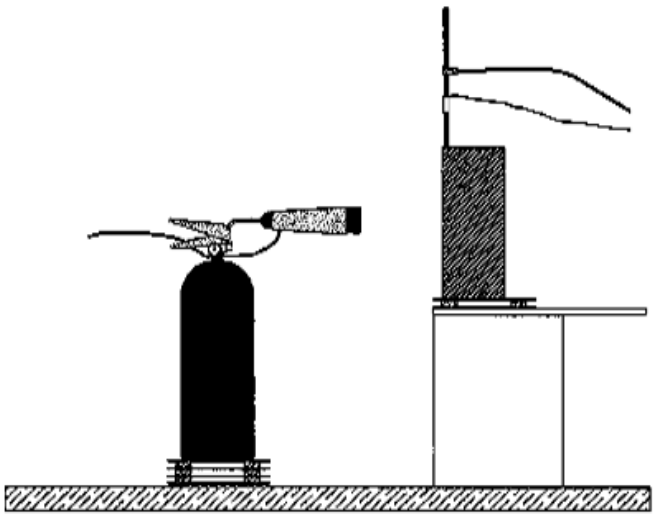

Figure 1 - Schematic of UL711 test setup for Class C rating

Figure 2 - FireIce extinguisher on isolated platform and remote actuator

Figure 3 - AC test system capable of 120kV phase to ground – 200mA output

2.2 Randall's Island Testing

Additional Class C testing was conducted as part of this test series at the Fire Department of New York (FDNY) Randal's Island Fire Academy. The Class C testing is a scaled up version of test setup for manual handline operations. The 12 by 12 inch target was replaced by a 138 kV disconnect switch from a substation, figure 5. The disconnect switch was energized using a power supply capable of supplying 50 kV mounted in a conEd Truck, figures 6 and 7. The nozzle was mounted to a platform constructed of pallets and moved using a pallet jack to adjust

the distance, figure 8. Measurements were collected using three multi meters, figure 9. Two collected current in milli-amps and micro-amps the third measured voltage across a 5000 ohm resistor. The 5000 ohm resistor data was calculated to find the leakage and provided a second check of the multimeter readings of straight leakage.

Figure 4 - 138 kV disconnect switch which was energized by a conEd Hi-Pot Truck

Figure 5 - conEd Truck with Power supply

Figure 6 - conEd power supply mounted in truck.

Figure 7 - Nozzle mounted to stack of pallets.

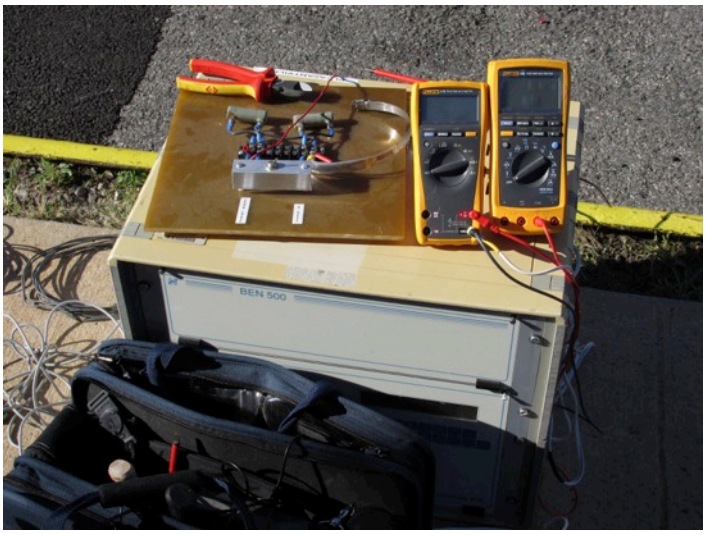

Figure 8 - Data acquisition from Multimeters and 5000 Ohm resister.

3.0 RESULTS

Ten tests were conducted at the conEd electrical test lab and sixteen tests were conducted at the FDNY Randal's Island Fire Academy over a two-day period. It is the desire of conEd and the FDNY to establish and verify safe practices for use of the FireIce product by means of a 2.5 gallon fire extinguisher and handline operations. FDNY and conEd are currently using the product on a limited basis during manual firefighter operations to extinguish Class C manhole and electrical pole fires. This test report is additional data to further justify the use of the fireice product on Class C Fires.

3.1 UL 711 Class C testing

During the UL711 testing each test varied the concentration, nozzle, and distance. The test result was a pass/fail with the leakage either remaining below the 0.9 mA threshold or resulting in an arc back to the can. The concentration refers to the amount of FireIce that was mixed with 2.5 gallons of distilled water. Two concentrations were used during testing: 90 grams and 100 grams per 2.5 gallons. Voltage remained at 100 kV and the distance was adjusted from 10 in to 30 inches. The extinguisher nozzle was changed during test from a fan tip nozzle with a spray of 15 degrees to a mist nozzle with a cone spray of 45 degrees. Table 1 contains the conditions and results for the ten (10) test conducted.

Table 2 - Test conditions including FireIce concentration, target voltage and standoff distance for the 10 tests conducted.

Test Number	Distance (in)	Voltage (kV)	Concentration (grams)	Nozzle	Pass / Fail
1	10	100	100	Fan Tip nozzle	Fail
2	20	100	100	Fan Tip nozzle	Fail
3	30	100	100	Fan Tip nozzle	Pass
4	30	100	90	Fan Tip nozzle	Pass
5	20	100	90	Fan Tip nozzle	Fail
6	20	100	90	Mist nozzle	Pass
7	10	100	90	Mist nozzle	Fail
8	15	100	90	Mist nozzle	Fail
9	10	100	Water Mist	Mist nozzle	Fail
10	10	100	Water Mist	Mist nozzle	Fail

Test 1 was conducted at 10 inches with 100 kV using a concentration of 100 grams. The extinguisher failed the test on activation of the actuator. During test 2 the extinguisher was moved back to 20 inches while the voltage and FireIce concentration remained the same. The extinguisher again failed however this time it was not during the activation or application of the agent, but upon release of the trigger. Test 3 moved the extinguisher back to 30 inches. The voltage and concentration remained the same. The extinguisher passed the test however there was an arc to the plastic curtain that surrounds the test setup to limit splatter. It is unclear if the results would have changed if the test was to have continued. The plastic curtain was pushed away from the test setup repeatedly, but due to build up of agent on the curtain the target continually arced to the plastic curtain during testing.

Test 4 was a repeat of test three at 30 inches with the target energized to 100 kV however the concentration was lowered to 90 grams. The extinguisher passed, however there was another arc to the plastic curtain. The lower concentration of FireIce results in a lower conductivity. It also

thins out the agent which would allow for more atomization when released from the extinguisher. The gaps of air between the agent (atomization) created during release are the biggest factor in determining if leakage occurs. A fine mist prevents leakage because air gaps are maintained producing a less conductive path for travel. This mist is more likely to be maintained when full pressure is available. When the trigger of the extinguisher is initiated and then released lower pressures can be seen which results in a “straight stream” of agent.

Test 5 moved the extinguisher in to 20 inches. The voltage remained at 100 kV and the concentration remained at 90 grams. The can failed at the start of the actuator.

Test 6 was a repeat of test 5 with a standoff distance of 20 inches, a voltage of 100 kV and a concentration of 90 grams. However the nozzle on the extinguisher was replaced with a water mist nozzle. This nozzle results in a wider more atomized spray. The extinguisher passed the test and the test ended when an arc to the plastic curtain occurred.

Test 7 moved the extinguisher to 10 inches, voltage and concentration remained at 100 kV and 90 grams respectively. The extinguisher failed.

Test 8 moved the to 15 inches, the extinguisher passed the test during the first release the extinguisher was then activated a second time and failed the test. The failure on the second release was likely due to the lower pressure available in the can.

Test 9 changed out the extinguisher to a Class C approved water mist that was placed at 10 inches. The target was energized to 100 kV. The extinguisher failed the test with implies that the test setup is not duplicating the test conducted at UL as the extinguisher was able to obtain a Class C rating. Two possible reasons could be that the target is not secured which can result in a rocking motion allowing the distance between the extinguisher and target to vary. The other potential difference is that the actuator may not match the one used by UL resulting in a difference in speed at which the trigger is engaged and therefore pressure at which the agent is released.

Test 9 was repeated during Test 10, the extinguisher had a lower pressure due to the release during Test 9. The extinguisher failed again. The testing was concluded after test 10 due to the actuator being destroyed.

After testing conEd supplied the resistivity measurement for the FireIce agent. conEd personal baselined a FireIce concentration of 100grams per 2.5 gallons of water to that of tap water and distilled water. Distilled water had a resistivity of 470 kΩ/cm while tap water drops to 12 kΩ/cm and FireIce to 0.8 kΩ/cm. This verified that FireIce is above the UL711 Class C acceptable conductivity of 1 μS/cm.

3.2 Randall’s Island Class C testing

The Randall’s island test setup was created to mimic the voltages which would be found in a conEd manhole fire. The result in a potential single phase voltage of 11,000 volts or 33,000 volts across all three (3) phases. The target was energized to 50,000 volts and the nozzle was placed at 30 feet to start.

Water Tests were conducted first to get a baseline for water applications utilizing the FireIce Setup. The nozzle was moved closer towards the target until a leakage of 900 mA was found.

The target was then energized to 11,000 volts and again the nozzle was moved toward the target until 900 mA was achieved with the FireIce product applied.

The leakage measurements were taken during the water and FireIce and water mixed (solution) using the FireIce induction system. The hose line was pressurized to 80 psi which resulted in a flow rate of approximately 110 GPM, figure 9. All readings were captured with a peack reading as the agent was in a steady state while the HiPot Truck ramped up to the desired voltage (or highest voltage capability in some tests). The Maximum lock function on the multimeters was used to capture the highest spike throughout the testing for a conservative approach (as well as three means to measure the leakage as mentioned above). All voltages were measured in DC.

Figure 9 - Hose stream striking energized target.

Table 3 - Test results for Randall's Island Class C Testing

Test Number	Distance (ft)	Voltage (kV)	Agent	Leakage (mA)*
1	31	30	Water	00.0
2	20	32 /27	Water	0.0
3	10	30-40	Water	0.08**
4	10	40	Water	0.04**
5	10	30	Water	0.036
6	10	30	Water	0.256
7	9	30	Water	1.254
8	9	11	Water	0.600
9	9.3	11	Water	2.3
10	9.3	11	FireIce	7.937
11	14.9	11	FireIce	0.207
12	14.9	11	FireIce	0.377
13	14.9	30	Water	0.885
14	14.9	30	FireIce	2.963
15	19.8	30	Water	0.004
16	19.8	30	FireIce	0.004

*Leakage takes background measurement into effect. Background leakage was approximately 0.7 – 1.4 uA

**Calculated leakage with 5000 ohm resistor in-line

Test 1 began with the nozzle at a distance of 31 feet. A distance of 25 feet is the current safe standoff distance for fire fighter personnel and is known to be conservative. Very little leakage was seen during the first 5 tests as the nozzle was moved toward the target. For each move the hose stream was stopped the target de-energized and the pallet was moved into the next location. The stream was then repositioned to have direct impingement on the target. With the agent hitting the target the power was returned to energize the target and the leakage was recorded.

After test 4 the DAQ was checked and it was discovered that the multimeters were bypassed and only the voltage across the 5000 ohm resistor was recording leakage. This had gone undetected due to the fact that very little if any leakage was occurring. The calculated leakage using the voltage across the 5000 ohm resistor and the leakage recorded by the multimeters were similarly low.

Test 5 repeated test 4 to confirm that the multimeters were properly recording the leakage and Test 6 repeated test 5 however the hose stream was adjusted to make better contact with the target. Similar to the Class C testing with the 2.5 gallon extinguisher, the largest factors affecting the leakage is the distance from the target, followed by the contact on the target (i.e. straight stream vs. mist/broken stream).

After test 7 the nozzle was moved to slightly forward to 9 feet which resulted in the first reading greater than 0.9 mA. This provides the unsafe attack distance for water at 30 kV. Test 8 then lowered the voltage to 11 kV to determine the safe attack distance at that voltage. At 9 feet the leakage dropped to 0.6 mA at the 11kV from 1.254 at 30 kV.

Test 9 was conducted at 9 ft 4 inches and it was observed that the stream had become a straight stream resulting in a leakage of 2.3 mA. Prior to this test the conductor placed across the nozzle opening to measure leakage was splitting the hose stream. This conductor broke allowing one solid stream and a higher leakage. The leakage measurement was good as the conductor still had significant contact with the water from the hose stream. After the test an additional conductor was placed in the nozzle to ensure solid contact with the stream.

Test 10 resulted in the highest reading of the day with a 7.9 mA leakage using the FireIce at 9.3 feet. This resulted in an unsafe distance for both water 2.3 mA and FireIce respectively.

During test 11 and 12 the nozzle was moved back to 14.9 feet where the leakage dropped to 0.207 and 0.377 for water and FireIce respectively. The 14.9 ft distance resulted in a safe distance for both water and FireIce at 11kV. However, the test demonstrates how rapidly the electrical leakage changes over a short distance (i.e. compared to the leakage at 9.3 ft). This finding is due to the leakage being a non-linear curve vs. a linear curve as first anticipated.

For tests 13 and 14 the distance remained at 14.9 ft. however the voltage was increased to 30 kV. The water resulted in a leakage of 0.885 a safe reading while the FireIce leakage increases to 2.963 mA, well over the 0.9 mA threshold. To determine a safe distance for FireIce at 30kV the nozzle was moved back to 19.8 ft and the leakage was measured. Both the water and the FireIce produce very little leakage with values measured at 0.004 mA for both agents. These tests show that for 11 kV and 30 kV the current safe attack distance of 25ft would provide a safe distance for both water and FireIce.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Class C testing of both the 2.5 gallon extinguisher assembly and the FireIce hose stream induction method showed that the FireIce agent can be used safely using current FDNY and conEd safety practices.

For the extinguisher assembly, the most conservative minimum work distance found was set by OSHA and was 3 ft. 4 in for 100kV. For 100 kV a distance of 3 ft. 4 in. (however a distance of 5 ft. is recommended), will provide a safe working distance for the FireIce extinguisher assuming the following:

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It should be noted that the 25 ft. limit is a critical distance and shall not be impeded under any conditions while applying the FireIce agent. It is recommended a safe area of protection be established at this 25 ft. minimum prior to setting up any manual fire fighting operations to attack a Class C fire.