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120 Volt Household Current Testing on Corrugated Stainless-Steel Tubing Types and Schedule 40 Black Iron Gas Piping.

Prepared For: National Association of State Fire Marshals
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February 16, 2018

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Executive Summary

Testing of four (4) Corrugated Stainless Steel Tubing (CSST) types, and schedule 40 black iron gas pipe was conducted to evaluate the ability of each product to defend against damage, wall perforation, and fire resulting from residential electrical system fault and electrical arcing to the gas pipe wall.

An electrical system fault was produced on a 15 amp 120 VAC RMS branch circuit. The fault test was conducted on a test set-up which placed gas piping test samples in contact with a metallic housing of an electrical appliance (recessed can light) which was energized with an electrical system fault. The test was conducted on five (5) separate wiring configurations of varied lengths and resistance.

Schedule 40 Black Iron Pipe
When energized, arcing occurred between the metal housing and gas pipe. The circuit faulted and tripped the circuit breaker. Both the metallic housing and the black iron pipe sustained damage at the point of contact. No perforations occurred to the black iron pipe over the five (5) trials as its wall thickness was sufficient to receive the resulting electrical arc, create a dead short, and enable the circuit breaker to open before pipe wall perforation occured.

Insulative outer jacketed CSST products – Gastite FlashShield™[1] black CSST and Ward Manufacturing (Ward Mfg.) WARDFlex®[2] yellow CSST
When energized, no arcing occurred and the circuit did not fault. Neither the metallic housing of the can light nor the insulative jacketed CSST products were damaged in any of the ten (10) tests.

Conductive outer jacketed CSST products – OmegaFlex® TracPipe® CounterStrike®[3] CSST and Ward Mfg. WARDFlex® Max[4] CSST
When energized, arcing occurred between the metal housing and the gas piping. The circuit faulted and tripped the breaker. Both the energized metal housing of the can light and the conductive jacketed CSST products sustained damage at the point of contact. Perforations through the CSST wall and gas fueled fires resulted in 9 out of 10 conductive jacketed CSST tests.

[1] Gastite FlashShield™ referred to as FlashShield™ in this report.
[2] Ward Mfg. WARDFlex® referred to as WARDFlex® in this report.
[3] OmegaFlex® TracPipe® CounterStrike® referred to as CounterStrike® in this report.
[4] Ward Mfg. WARDFlex® Max referred to as WARDFlex® Max in this report.

Overview

Residential gas line plumbing allows for various types of gas piping systems. Some of these variations include material composition, flexible vs. non-flexible piping, conductive outer jacket vs. insulative outer jacket, wall thickness, color, etc.

This testing was to provide insight into the effects of 120 Volt household electrical current when faulted to several types of CSST gas tubing and to black iron piping. Each product was tested with five (5) different circuit configurations of various resistances.

Figure 1 Electrical Short to Light Fixture Housing.

An ungrounded recessed light fixture was installed so that the hot conductor (black wire) was shorted to the light fixture housing (see Figure 1). Turning on the switch to the light energized the casing to the light fixture. Without an equipment ground wire, the casing on the light fixture becomes energized. Depending on the type of gas pipe, a potential path to ground may then be introduced via contact between the light fixture and the grounded gas pipe.

The effects of household electrical current when faulted to some of the various types of gas piping and the impact on the gas pipe as well as the light fixture is documented within this report. There are five (5) different products represented in the tests described IN this report. The gas piping products tested are as follows:

1. WARDFlex® CSST;
2. Schedule 40 Black Iron Pipe;
3. CounterStrike® CSST;
4. FlashShield™ CSST; and
5. WARDFlex® Max CSST.

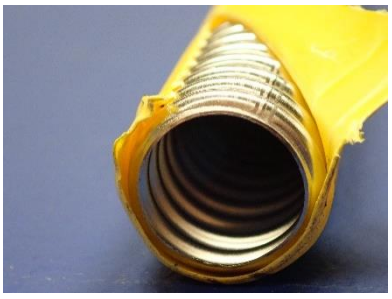


Figure 4 Yellow WARDFlex® CSST.

Figure 3 Schedule 40 - Black Iron Pipe.

Figure 2 CounterStrike® CSST.

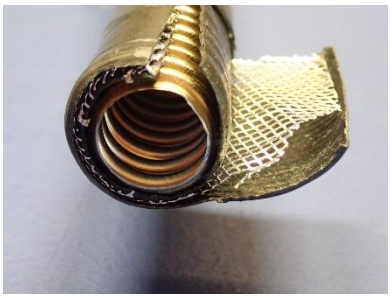


Figure 6 FlashShield™ CSST.

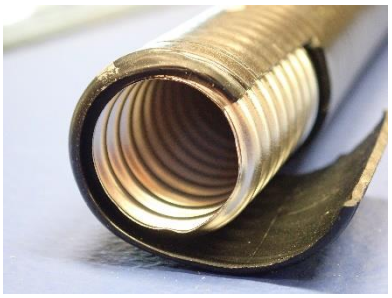


Figure 5 WARDFlex® Max CSST.

Testing Set-Up (See Appendix A)

Framing/Construction

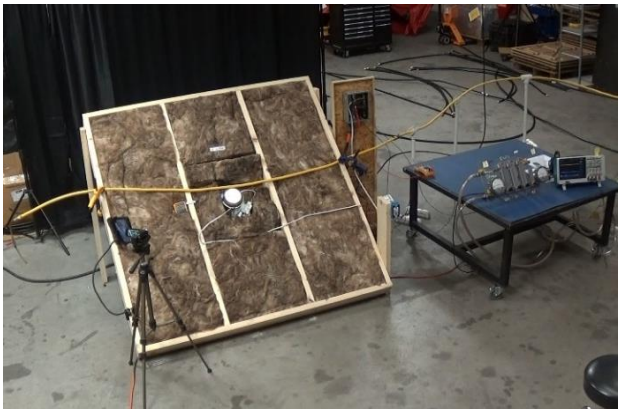



Figure 7 Overview of Test Set.

A 6-foot by 6-foot test frame, angled approximately 45 degrees with ½-inch sheetrock underneath, contained a recessed light fixture in the center. This frame, constructed of 2-inch by 6-inch lumber on 24-inch centers, contained three joist spaces filled with fiberglass insulation representing an attic.

Tests consisted of 30 feet of gas pipe with a 20-foot section coupled together with a 10-foot section. The 10-foot length of pipe was then marked with an arrow 5 feet from the coupling. This mark served as the 25-foot point of contact for the testing. The gas pipe was then placed across the metal housing of a recessed light fixture so that the gas pipe and the metal housing were in direct contact. The recessed light fixture and the gas pipe were marked with the test number at the location of contact.

Gas System

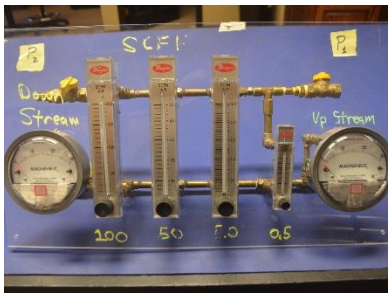
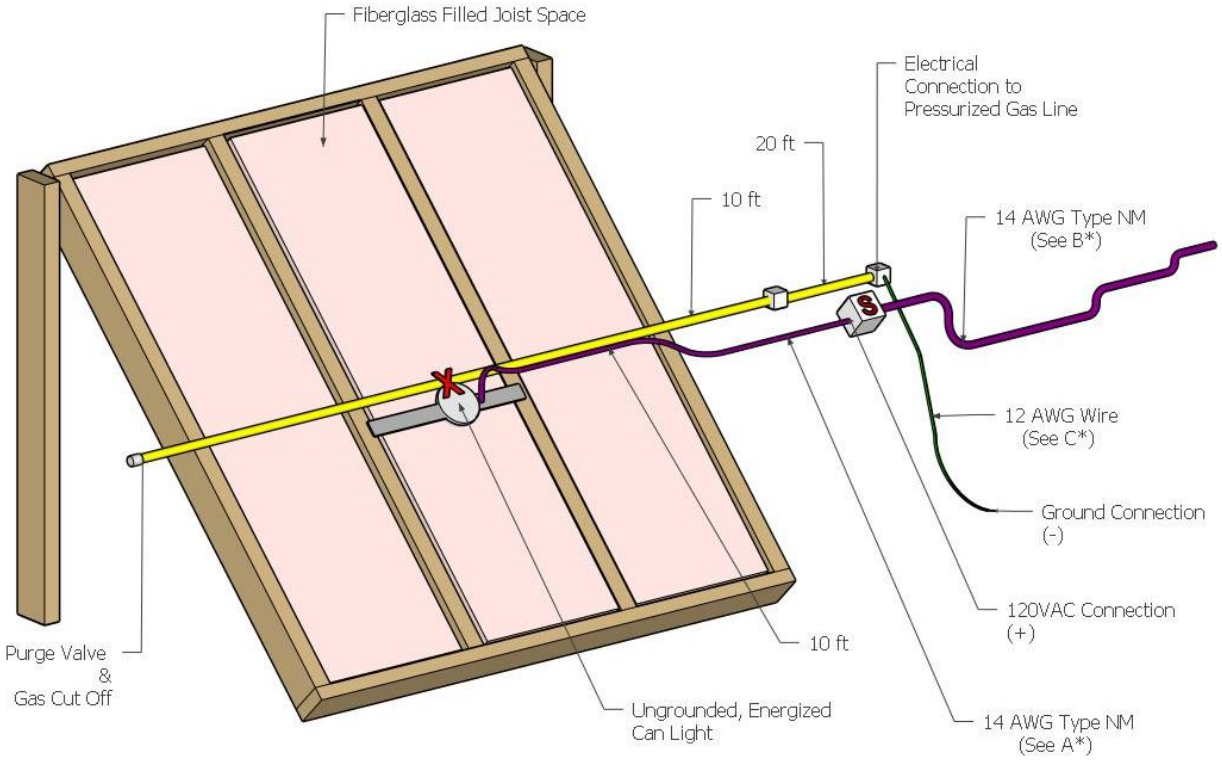



Figure 8 99.97% methane gas cylinder used for testing (left), flow and pressure gauges used in testing (center & right), system pressure between 7 and 9 inches of water column (right).

During testing the gas system was pressurized with methane (an appropriate substitute for natural gas) between 7 to 9 inches of water column. The gas from a 99.97% methane gas cylinder flows through a 3-stage regulator system (Tank, 10 PSI, & 2 PSI) before entering the flow and pressure gauge assembly shown in Figure 8. The gas flowed through the assembly and into the test pipe. The system was purged for each test via a cutoff valve at the end of the gas pipe system (see Figure 9).



*Lengths vary based on respective values in Appendix C

Figure 9 Test configuration. Not to scale.

Numerical Identification of Testing Conducted

Each test is identified in "x.x" form, with the first number representing the type of gas piping product tested, and the second number being a reference to the length of the wires used in the circuit for that specific test. For example, as shown in Appendix C, Test 1.1 uses WARDFlex® CSST with a yellow, insulative outer jacket. For the circuit length as viewed in Figure 9, wire length "A" is 10 feet and "B" is 5 feet for a sum of 15 feet of 14 AWG (American Wire Gauge) on the 'hot' side. Wire length "C" consists of 15 feet of 12 AWG on the neutral/return side.

Energizing Circuit Information

The testing utilized a 15 amp, 120 VAC RMS branch circuit with various lengths of conductors (see Figure 9). A ground fault condition in the ungrounded recessed can light was created by damaging the 'hot' conductor's insulation and pinching it underneath the fixture's junction box cover plate (see Figure 1 Electrical Short to Light Fixture Housing.). For each test, the circuit was energized by turning ON a light switch. This resulted in the recessed light fixture's metal housing becoming energized at 120 VAC RMS.

Test Equipment

Table 1 Equipment list.

Manufacturer	Equipment	Model Number
EXTECH Instruments	Milliohm Meter	380580
Fluke	True RMS Multimeter	233

Testing

1. WARDFlex® - Yellow Jacket

Overview of Test 1.1 – Test 1.5 (see Appendix C for complete list)

Yellow jacketed WARDFlex® consists of a single layer, insulative outer plastic jacket covering CSST tubing. The same 10-foot section of yellow jacketed WARDFlex® was reused for all 5 different tests. For each different test, the 10-foot piece of WARDFlex® was repositioned, providing a new point of contact.

When energized, the circuit showed no faulting. The circuit breaker did not trip. The recessed light fixture's metal housing remained energized at the circuit potential until manually de-energized after an approximate 30 second wait.

Neither the recessed light fixture's housing nor the yellow jacketed WARDFlex® CSST sustained any damage.

No fires resulted.

Figure 10 WARDFlex® in contact with recessed light.

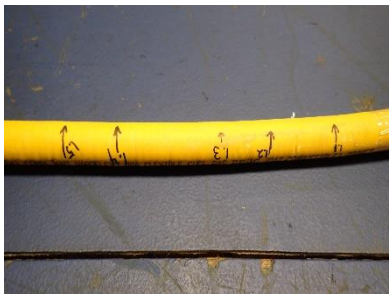


Figure 11 The five test locations.

Table 2 Test 1 summary.

Test No.	Gas Pipe	A #14 (Hot)	B #14 (Hot)	C #12 (GRD)	Circuit Breaker Size	Date Code	Voltage (RMS)	Hole (Y/N)	Fire (Y/N)	Gas Flow Rate (SCFH Air)
1.1	Yellow WARDFlex®	10 ft.	5 ft.	15 ft.	15a	1736	126.7	No	No	0
1.2	Yellow WARDFlex®	10 ft.	40 ft.	50 ft.	15a	1736	127.3	No	No	0
1.3	Yellow WARDFlex®	10 ft.	90 ft.	100 ft.	15a	1736	126.2	No	No	0
1.4	Yellow WARDFlex®	10 ft.	140 ft.	150 ft.	15a	1736	126.4	No	No	0
1.5	Yellow WARDFlex®	10 ft.	190 ft.	200 ft.	15a	1736	126.4	No	No	0

See Schematic on page 7 of 31 (Figure 9) where A, B, and C are described as (A) wire length from switch to light, (B) wire length from circuit breaker to switch, & (C) wire length from cold water ground clamp on gas pipe to ground bus in circuit breaker panel.

Test 1.1

Figure 12 Test 1.1 in place (left). Undamaged WARDFlex® (center) and light fixture (right) post-test.

When the light switch was turned ON, the light came on, but there was no electrical activity. The circuit breaker did not trip. Neither the recessed lighting fixture nor the yellow jacketed WARDFlex® CSST sustained any damage.

Test 1.2

Figure 13 Test 1.2 in place (left). Undamaged WARDFlex® (center) and light fixture (right) post-test.

When the light switch was turned ON, the light came on, but there was no electrical activity. The circuit breaker did not trip. Neither the recessed lighting fixture nor the yellow jacketed WARDFlex® CSST sustained any damage.

Test 1.3

Figure 14 Test 1.3 in place (left & center). Undamaged WARDFlex® and light fixture (right) post-test.

When the light switch was turned ON, the light came on, but there was no electrical activity. The circuit breaker did not trip. Neither the recessed lighting fixture nor the yellow jacketed WARDFlex® CSST sustained any damage.

Test 1.4

Figure 15 Test 1.4 in place (left & center). Undamaged WARDFlex® and light fixture (right) post-test.

When the light switch was turned ON, the light came on, but there was no electrical activity. The circuit breaker did not trip. Neither the recessed lighting fixture housing nor the yellow jacketed WARDFlex® CSST sustained any damage.

Test 1.5

Figure 16 Test 1.5 in place (left & center). Undamaged light fixture post-test (right).

When the light switch was turned ON, the light came on, but there was no electrical activity. The circuit did not trip the breaker. Neither the recessed light fixture's housing nor the yellow jacketed WARDFlex® CSST sustained any damage.

2. Black Iron Pipe

Overview of Test 2.1 – Test 2.5 (see Appendix C for complete list)

Black iron pipe (BIP) is a conductive, rigid, metal pipe. The same 10-foot section of BIP was reused for the 5 different tests. For each test, the same pipe was rotated, providing a new point of contact.

When energized, the circuit faulted and tripped the circuit breaker. Both the recessed light fixture's housing and the BIP sustained minor surface damage at the point of contact.

No perforations occurred in either the recessed light fixture or the BIP throughout this series of testing.

No fires resulted.

Figure 17 Test 2 layout.

Figure 18 Result of Test 2.1.

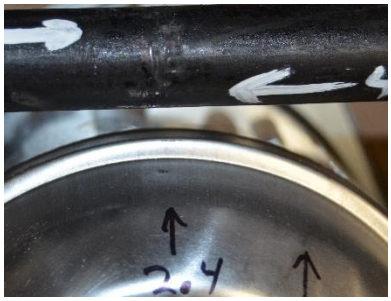


Figure 19 Results of Test 2.4.

Table 3 Test 2 summary.

Test No.	Gas Pipe	A #14 (Hot)	B #14 (Hot)	C #12 (GRD)	Circuit Breaker Size	Date Code	Voltage (RMS)	Hole (Y/N)	Fire (Y/N)	Gas Flow Rate (SCFH Air)
2.1	Black Iron Pipe	10 ft.	5 ft.	15 ft.	15 amp	N/A	126.8	No	No	0
2.2	Black Iron Pipe	10 ft.	40 ft.	50 ft.	15 amp	N/A	125.6	No	No	0
2.3	Black Iron Pipe	10 ft.	90 ft.	100 ft.	15 amp	N/A	127.5	No	No	0
2.4	Black Iron Pipe	10 ft.	140 ft.	150 ft.	15 amp	N/A	127.0	No	No	0
2.5	Black Iron Pipe	10 ft.	190 ft.	200 ft.	15 amp	N/A	127.0	No	No	0

See Schematic on page 7 of 31 (Figure 9) where A, B, and C are described as(A) wire length from switch to light, (B) wire length from circuit breaker to switch, & (C) wire length from cold water ground clamp on gas pipe to ground bus in circuit breaker panel.

Test 2.1

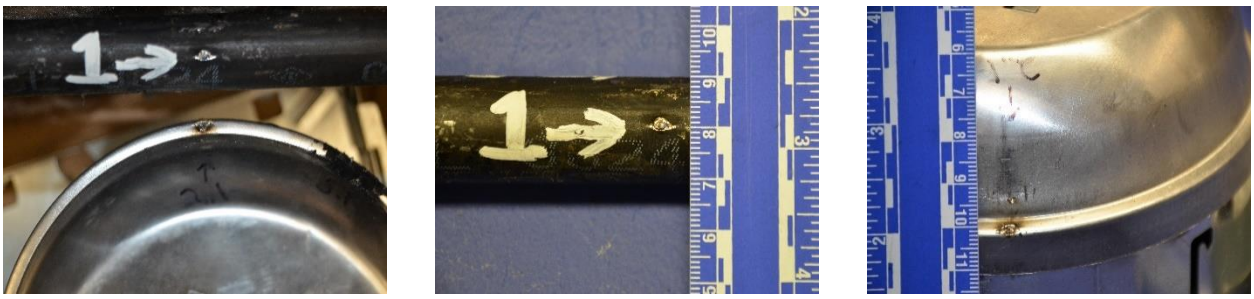


Figure 20 Test 2.1 post-test damage.

When the light switch was turned ON, an arc occurred between the light fixture housing and the gas pipe. The circuit breaker did trip, de-energizing the circuit without perforating the gas pipe. The recessed light fixture's metal housing sustained minor surface damage in the form of a small arc mark, accompanied by localized discoloration. The black iron pipe also sustained a corresponding arc mark.

Test 2.2

Figure 21 Test 2.2 post-test damage.

When the light switch was turned ON, an arc occurred between the light fixture housing and the gas pipe. The circuit breaker did trip, de-energizing the circuit without perforating the gas pipe. The recessed light fixture's metal housing sustained minor surface damage in the form of a small arc mark, accompanied by localized discoloration. The black iron pipe also sustained a corresponding arc mark.

Test 2.3

Figure 22 Test 2.3 post-test damage.

When the light switch was turned ON, an arc occurred between the light fixture housing and the gas pipe. The circuit breaker did trip, de-energizing the circuit without perforating the gas pipe. The recessed light fixture's metal housing sustained minor surface damage in the form of a small arc mark, accompanied by localized discoloration. The black iron pipe also sustained a corresponding arc mark.

Test 2.4

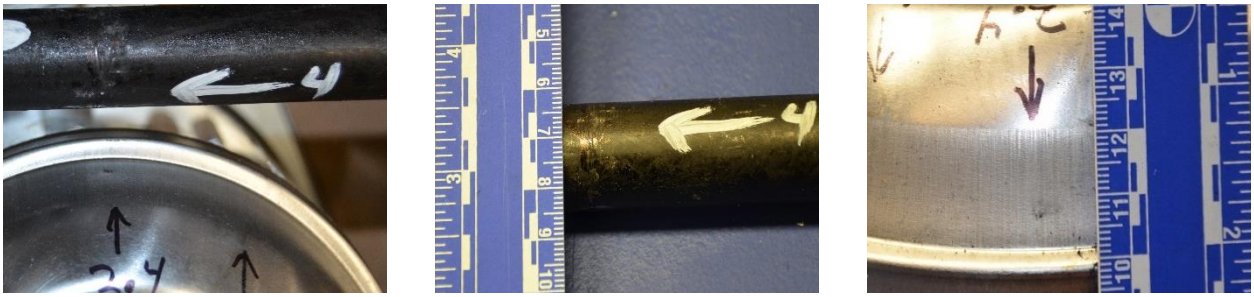


Figure 23 Test 2.4 post-test damage.

When the light switch was turned ON, an arc occurred between the light fixture housing and the gas pipe. The circuit breaker did trip, de-energizing the circuit without perforating the gas pipe. The recessed light fixture's metal housing sustained minor surface damage in the form of a small arc mark, accompanied by localized discoloration. The black iron pipe also sustained a corresponding arc mark.

Test 2.5

Figure 24 Test 2.5 post-test damage.

When the light switch was turned ON, an arc occurred between the light fixture housing and the gas pipe. The circuit breaker did trip, de-energizing the circuit without perforating the gas pipe. The recessed light fixture's metal housing sustained minor surface damage in the form of a small arc mark, accompanied by localized discoloration. The black iron pipe also sustained a corresponding arc mark.

3. CounterStrike®

Overview of Test 3.1 – Test 3.5 (see Appendix C for complete list)

Figure 25 Test series 3 in place (left). Range of damage incurred to CounterStrike® CSST across test series 3 (center & right).

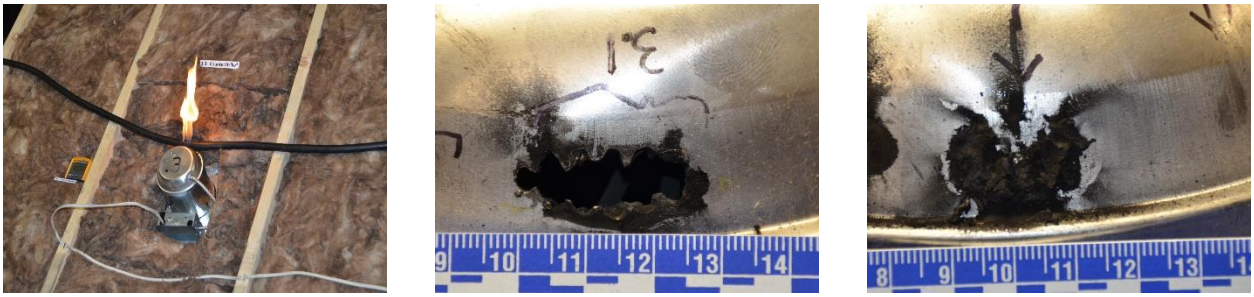


Figure 26 Example of fire resulting during test series 3 (left). Range of damage incurred to light fixtures across test series 3 (center & right).

CounterStrike® CSST is a flexible gas pipe with a single layer, conductive outer plastic jacket. Each of the 5 tests used a new 10-foot test section of CounterStrike® CSST for the point of contact.

When energized, arcing occurred between the gas pipe's outer jacket and the recessed light housing. The circuit faulted and tripped the circuit breaker. Both the recessed light fixture's housing and the CounterStrike® CSST sustained damage. The damage varied, from perforations spanning approximately 6 corrugations in length, to unperforated pits on both the CSST and the light fixture.

Perforations occurred in both the recessed light fixture's metal housing and the CounterStrike® CSST in 4 of the 5 tests. Once perforated, the flow rate for the escaping gas was measured before moving the gas pipe.

Fires resulted in 4 out of 5 tests within this series.

Table 4 Test 3 summary.

Test No.	Gas Pipe	A #14 (Hot)	B #14 (Hot)	C #12 (GRD)	Circuit Breaker Size	Date Code	Voltage (RMS)	Hole (Y/N)	Fire (Y/N)	Gas Flow Rate (SCFH Air)
3.1	CounterStrike®	10 ft.	5 ft.	15 ft.	15 amp	1740	126.9	Yes	Yes	9
3.2	CounterStrike®	10 ft.	40 ft.	50 ft.	15 amp	1740	127.4	Yes	Yes	11
3.3	CounterStrike®	10 ft.	90 ft.	100 ft.	15 amp	1740	126.8	Yes	Yes	10
3.4	CounterStrike®	10 ft.	140 ft.	150 ft.	15 amp	1740	126.9	Yes	Yes	8.5
3.5	CounterStrike®	10 ft.	190 ft.	200 ft.	15 amp	1740	126.9	No	No	0

See Schematic on page 7 of 31 (Figure 9) where A, B, and C are described as (A) wire length from switch to light, (B) wire length from circuit breaker to switch, & (C) wire length from cold water ground clamp on gas pipe to ground bus in circuit breaker panel.

Test 3.1

Figure 27 Damage to CounterStrike® CSST in test 3.1.

Figure 28 Damage to light fixture in test 3.1.

When the light switch was turned ON, arcing occurred between the light fixture housing and the gas pipe. The circuit breaker did trip, de-energizing the circuit.

The recessed light fixture's metal housing sustained damage, leaving a hole matching the corrugations of the CSST gas pipe. The perforations span approximately 6 corrugations in length.

The CounterStrike® CSST gas pipe sustained similar damage. The perforations span approximately 6 corrugations in length.

Figure 29 Test 3.1 fire.

Perforations did occur in both the light fixture's metal housing and the CounterStrike® CSST gas pipe.

A fire did result.

Test 3.2

Figure 30 Damage to CounterStrike® CSST in test 3.2.

Figure 31 Damage to light fixture in test 3.2.

When the light switch was turned ON, arcing occurred between the light fixture housing and the gas pipe. The circuit breaker did trip, de-energizing the circuit.

Perforations occurred in both the light's metal housing and the CounterStrike® CSST gas pipe.

The recessed light fixture's metal housing sustained damage, leaving a series of holes matching the corrugations of the CSST gas pipe. The damage spans approximately 5 corrugations.

Figure 32 Test 3.2 fire.

The CounterStrike® CSST gas pipe sustained damage. The perforations span approximately 5 corrugations.

A fire did result.

Test 3.3

Figure 33 Damage to CounterStrike® CSST in test 3.3.

Figure 34 Damage to light fixture in test 3.3.

When the light switch was turned ON, arcing occurred between the light fixture housing and the gas pipe. The circuit breaker did trip, de-energizing the circuit.

Perforations occurred in both the metal housing and the CounterStrike® CSST gas pipe.

The recessed light fixture's metal housing sustained damage, leaving a damaged area that matched the corrugations of the CSST gas pipe, and these holes span approximately 3 corrugations.

Figure 35 Fire resulting from test 3.3.

The CounterStrike® CSST gas pipe sustained damage. The perforations span approximately 3 corrugations.

A fire did result.

Test 3.4

Figure 36 Damage to CounterStrike® CSST in test 3.4.

Figure 37 Damage to light fixture in test 3.4.

When the light switch was turned ON, arcing occurred between the light fixture housing and the gas pipe. The circuit breaker did trip, de-energizing the circuit.

Perforations occurred in both the light's metal housing and the CounterStrike® CSST gas pipe.

The recessed light fixture's metal housing sustained damage, leaving a series of holes matching the corrugations of the CSST gas pipe, and these holes span approximately 4 corrugations in length.

Figure 38 Test 3.4 fire.

The CounterStrike® CSST gas pipe sustained similar damage. The perforations span approximately 4 corrugations in length.

A fire did result.

Test 3.5

Figure 39 Damage to CounterStrike® CSST in test 3.5.

Figure 40 Damage to light fixture in test 3.5.

When the light switch was turned ON, arcing occurred between the light fixture housing and the gas pipe. The circuit breaker did trip, de-energizing the circuit.

The recessed light fixture's metal housing did sustain damage. There was an accumulation of soot build-up, and a small pit in the fixture's metal housing.

The CounterStrike® CSST gas pipe sustained damage to its conductive outer jacket. Within the area of material loss, there was a small arc mark on the underlying stainless-steel tubing.

No perforations developed in either the recessed light's metal housing or the CounterStrike® CSST gas pipe.

No fire resulted.

4. FlashShield™

Overview of Test 4.1 – Test 4.5 (see Appendix C for complete list)

FlashShield™ possesses a 3-layer outer jacket. The bottom layer, or layer closest to the CSST, is a semi-conductive polymer (plastic). The middle layer is a conductive aluminum mesh. The top layer, or outermost layer, is an insulative polymer (plastic). Each of the 5 tests used a new 10-foot section. When energized, the circuit did not fault. The circuit breaker did not trip. The recessed light fixture's metal housing remained energized at the circuit potential until manually de-energized after an approximate 30 second wait.

Neither the recessed light fixture's housing nor the FlashShield™ CSST sustained any damage.

No fires resulted.

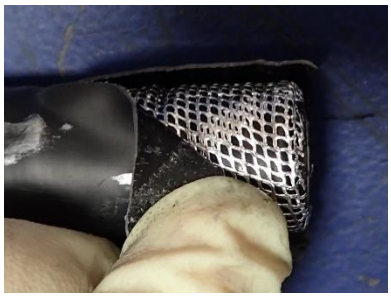


Figure 41 FlashShield™ CSST aluminum mesh layer visible.

Figure 42 FlashShield™ CSST in contact with recessed light fixture.

Table 5 Test 4 summary.

Test No.	Gas Pipe	A #14 (Hot)	B #14 (Hot)	C #12 (GRD)	Circuit Breaker Size	Date Code	Voltage (RMS)	Hole (Y/N)	Fire (Y/N)	Gas Flow Rate (SCFH Air)
4.1	FlashShield™	10 ft.	5 ft.	15 ft.	15 amp	1739	126.7	No	No	0
4.2	FlashShield™	10 ft.	40 ft.	50 ft.	15 amp	1739	125.0	No	No	0
4.3	FlashShield™	10 ft.	90 ft.	100 ft.	15 amp	1739	125.8	No	No	0
4.4	FlashShield™	10 ft.	140 ft.	150 ft.	15 amp	1739	126.0	No	No	0
4.5	FlashShield™	10 ft.	190 ft.	200 ft.	15 amp	1739	126.2	No	No	0

See Schematic on page 7 of 31 (Figure 9) where A, B, and C are described as (A) wire length from switch to light, (B) wire length from circuit breaker to switch, & (C) wire length from cold water ground clamp on gas pipe to ground bus in circuit breaker panel.

Test 4.1

Figure 43 Test 4.1 in place (left). Undamaged FlashShield™ (center) and light fixture (right) post-test.

When the light switch was turned ON, the light came on, but there was no electrical activity. The circuit breaker did not trip. Neither the recessed light fixture's housing nor the FlashShield™ CSST sustained any damage.

Test 4.2

Figure 44 Test 4.2 in place (left). Undamaged FlashShield™ (center) & light fixture (right) post-test.

When the light switch was turned ON, the light came on, but there was no electrical activity. The circuit breaker did not trip. Neither the recessed light fixture's housing nor the FlashShield™ CSST sustained any damage.

Test 4.3

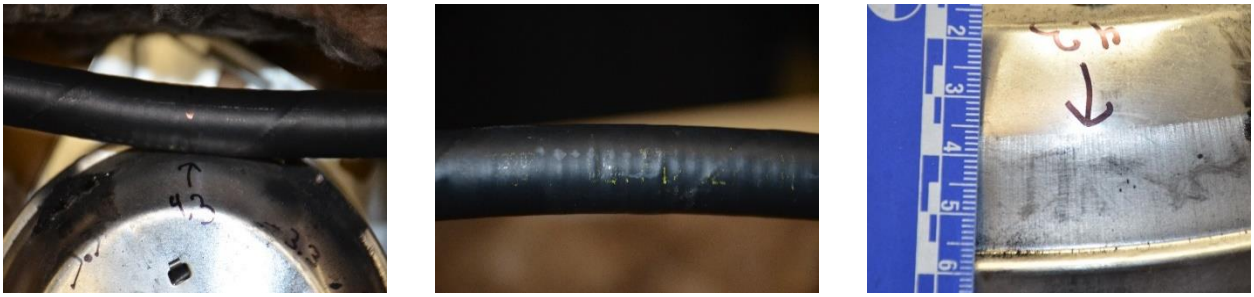


Figure 45 Test 4.3 in place (left). Undamaged FlashShield™ (center) & light fixture (right) post-test.

When the light switch was turned ON, the light came on, but there was no electrical activity. The circuit breaker did not trip. Neither the recessed light fixture's housing nor the FlashShield™ CSST sustained any damage.

Test 4.4

Figure 46 Test 4.4 in place (left). Undamaged FlashShield™ CSST (center) & light fixture (right) post-test.

When the light switch was turned ON, the light came on, but there was no electrical activity. The circuit breaker did not trip. Neither the recessed light fixture's housing nor the FlashShield™ CSST sustained any damage.

Test 4.5

Figure 47 Test 4.5 in place (left). Undamaged FlashShield™ (center) & light fixture (right) post-test.

When the light switch was turned ON, the light came on, but there was no electrical activity. The circuit breaker did not trip. Neither the recessed light fixture's housing nor the FlashShield™ CSST sustained any damage.

5. WARDFlex® Max

Overview of Test 5.1 – Test 5.5 (see Appendix C for complete list)



Figure 48 Test series 5 in place (left). Range of damage to WARDFlex® Max CSST in series 5 testing (center & right).

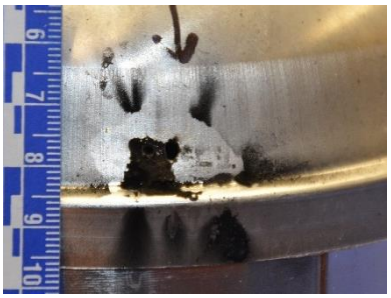
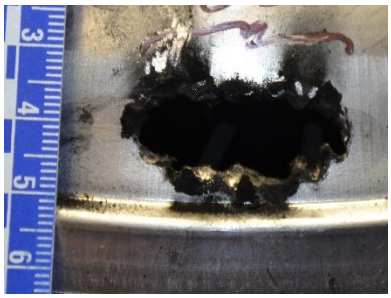




Figure 49 Example of fire resulting in test series 5 (left). Range of damage to light fixtures in series 5 testing (center & right).

WARDFlex® Max CSST is a flexible gas pipe with a single layer, conductive, outer plastic jacket. Each of the 5 tests used a new 10-foot test section of WARDFlex® Max CSST for the point of contact.

When energized, arcing occurred between the gas pipe and light fixture's metal housing. The circuit faulted and tripped the circuit breaker. Both the recessed light fixture's housing and the WARDFlex® Max CSST sustained damage. The perforations ranged in damage from approximately 3 to 11 corrugations.

Perforations occurred in both the recessed light fixture's metal housing and the WARDFlex® Max CSST in all 5 tests. Once perforated, the flow rate for the escaping gas was measured before moving the gas pipe.

Figure 50 WARDFlex® Max CSST outer jacket burning without gas.

Fires resulted in all 5 tests.

Table 6 Test 5 summary.

Test No.	Gas Pipe	A #14 (Hot)	B #14 (Hot)	C #12 (GRD)	Circuit Breaker Size	Date Code	Voltage (RMS)	Hole (Y/N)	Fire (Y/N)	Gas Flow Rate (SCFH Air)
5.1	WARDFlex® Max	10 ft.	5 ft.	15 ft.	15 amp	1723	126.1	Yes	Yes	9.5
5.2	WARDFlex® Max	10 ft.	40 ft.	50 ft.	15 amp	1723	127.6	Yes	Yes	11.75
5.3	WARDFlex® Max	10 ft.	90 ft.	100 ft.	15 amp	1723	126.7	Yes	Yes	11.75
5.4	WARDFlex® Max	10 ft.	140 ft.	150 ft.	15 amp	1723	127.0	Yes	Yes	10
5.5	WARDFlex® Max	10 ft.	190 ft.	200 ft.	15 amp	1723	126.4	Yes	Yes	9

See Schematic on page 7 of 31 (Figure 9) where A, B, and C are described as (A) wire length from switch to light, (B) wire length from circuit breaker to switch, & (C) wire length from cold water ground clamp on gas pipe to ground bus in circuit breaker panel.

Test 5.1

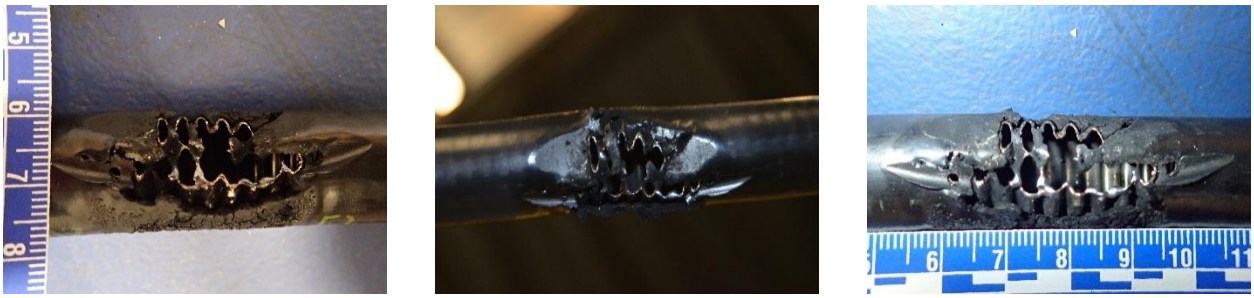


Figure 51 Damage to WARDFlex® Max CSST in test 5.1.

Figure 52 Damage to light fixture in test 5.1.

When the light switch was turned ON, arcing occurred between the light fixture housing and the gas pipe. The circuit breaker did trip, de-energizing the circuit.

Perforations occurred in both the light's metal housing and the WARDFlex® Max CSST gas pipe.

The recessed light fixture's metal housing sustained damage, leaving a series of holes matching the corrugations of the CSST gas pipe. The damage stretched approximately 11 corrugations in length.

Figure 53 Test 5.1 fire.

The WARDFlex® Max CSST gas pipe sustained damage. The perforations stretched approximately 11 corrugations.

A fire did result.

Test 5.2

Figure 54 Damage to WARDFlex® Max CSST in test 5.2.

Figure 55 Damage to light fixture in test 5.2.

When the light switch was turned ON, arcing occurred between the light fixture housing and the gas pipe. The circuit breaker did trip, de-energizing the circuit.

Perforations occurred in both the light's metal housing and the WARDFlex® Max CSST gas pipe.

The recessed light fixture's metal housing sustained damage, leaving a series of holes matching the corrugations of the CSST gas pipe. The damage stretched approximately 9 corrugations in length.

The WARDFlex® Max CSST gas pipe sustained damage. The perforations stretched approximately 9 corrugations in length.

A fire did result.

Figure 56 Test 5.2 fire.

Figure 57 WARDFlex® Max outer jacket burning with gas turned off.

Test 5.3

Figure 58 Damage to WARDFlex® Max CSST in test 5.3.

Figure 59 Damage to light fixture in test 5.3.

When the light switch was turned ON, arcing occurred between the light fixture housing and the gas pipe. The circuit breaker did trip, de-energizing the circuit.

Perforations occurred in both the light's metal housing and the WARDFlex® Max CSST gas pipe.

The recessed light fixture's metal housing sustained damage, leaving a series of holes matching the corrugations of the CSST gas pipe. The damage stretched approximately 7 corrugations in length.

The WARDFlex® Max CSST gas pipe sustained damage. The perforations stretched approximately 7 corrugations in length.

A fire did result.

Figure 60 Fire resulting from test 5.3.

Figure 61 WARDFlex® Max outer jacket burning with gas turned off.

Test 5.4

Figure 62 Damage to WARDFlex® Max CSST in test 5.4.

Figure 63 Damage to light fixture in test 5.4.

When the light switch was turned ON, arcing occurred between the light fixture housing and the gas pipe. The circuit breaker did trip, de-energizing the circuit.

Perforations occurred in both the light's metal housing and the WARDFlex® Max CSST gas pipe.

The recessed light fixture's metal housing sustained damage, leaving a series of holes matching the corrugations of the CSST gas pipe. The damage stretched approximately 4 corrugations in length.

The WARDFlex® Max CSST gas pipe sustained damage. The perforations stretched approximately 4 corrugations in length.

A fire did result.

Figure 64 Test 5.4 fire, inside the light fixture's housing.

Test 5.5

Figure 65 Damage to WARDFlex® Max CSST in test 5.5.

Figure 66 Damage to light fixture in test 5.5.

When the light switch was turned ON, arcing occurred between the light fixture housing and the gas pipe. The circuit breaker did trip, de-energizing the circuit.

Perforations occurred in both the light's metal housing and the WARDFlex® Max CSST gas pipe.

The recessed light fixture's metal housing sustained damage, leaving a series of holes matching the corrugations of the CSST gas pipe. The damage stretched approximately 3 corrugations in length.

The WARDFlex® Max CSST gas pipe sustained damage. The perforations stretched approximately 3 corrugations in length.

A fire did result with flame inside the recessed light's housing.

Figure 67 Test 5.5 escaping gas sustained burning on the inside of the recessed light's fixture's housing.

Appendix A

Test Procedure

1. Lay out the gas piping as depicted in diagram (Figure 9).
2. Position the gas pipe so it is in contact with the ungrounded recessed can light with an internal ground-fault condition.
3. Pressurize the gas system with natural gas to 7 to 9 inches of water column.
4. Bleed the air out of the gas system.
5. Purge the gas system of air.
6. Set meter to capture voltage measurement.
7. Start the video recording equipment.
8. Turn the circuit breaker to the ON position.
9. Energize the recessed can light by turning ON the switch for the light fixture.
10. Document the results of the test in the appropriate columns on the test list (Appendix C).
11. Record the information and save the data.
12. Turn switch for recessed can light to OFF position.
13. Turn circuit breaker to OFF position.

Appendix B

Data Acquisition

- DSLR Camera
- (2) Video Cameras (Sony HDR-CX240 & Canon Vixia HF R30)
- iPad (Slow Motion View)
- Multi-Meter (Fluke 233)
- Milliohm meter (Extech 380580)

Test Material List

8	2”x6” ×8’s Lumber for Wood Frame
36 sq. ft.	R19 Fiberglass Batt Insulation
1 sheet	½” Drywall
5	6” Recessed Can Light Fixtures
1	6” Can Light Trim & Bulb
100 ft.	Yellow WARDFlex® CSST
2	½” WARDFlex® Connectors
1	½” WARDFlex® Coupling
100 ft.	½” WARDFlex® Max CSST
2	½” WARDFlex® Max Connectors
1	½” WARDFlex® Max Coupling
100 ft.	½” FlashShield™ CSST
2	½” FlashShield™ Connectors
1	½” FlashShield™ Coupling
100 ft.	½” CounterStrike® CSST
2	½” CounterStrike® Connectors
1	½” CounterStrike® Coupling
70 ft.	½” Schedule 40 Black Iron Gas Pipe
1	½” Black Iron Union
500 ft.	12/2 with Ground Type NM
500 ft.	14/2 with Ground Type NM
1	15 Amp/Single-Pole Circuit Breaker

Appendix C

Test Summary

Test No.	Gas Pipe	Wire Lengths in Circuit A #14 (Hot)	B #14 (Hot)	C #12 (GRD)	Circuit Breaker Size	Date Code	Voltage (RMS)	Hole (Y/N)	Fire (Y/N)	Gas Flow Rate (SCFH Air)	Test Date	Test Sequence
1.1	WARDFlex®- Yellow	10 ft.	5 ft.	15 ft.	15 amp	1736	126.7	No	No	0	12/18/2017	4
1.2	WARDFlex®- Yellow	10 ft.	40 ft.	50 ft.	15 amp	1736	127.3	No	No	0	12/18/2017	5
1.3	WARDFlex®- Yellow	10 ft.	90 ft.	100 ft.	15 amp	1736	126.2	No	No	0	12/18/2017	9
1.4	WARDFlex®- Yellow	10 ft.	140 ft.	150 ft.	15 amp	1736	126.4	No	No	0	12/18/2017	10
1.5	WARDFlex®- Yellow	10 ft.	190 ft.	200 ft.	15 amp	1736	126.4	No	No	0	12/18/2017	11
2.1	Black Iron Pipe	10 ft.	5 ft.	15 ft.	15 amp	170921	126.8	No	No	0	12/19/2017	12
2.2	Black Iron Pipe	10 ft.	40 ft.	50 ft.	15 amp	170921	125.6	No	No	0	12/19/2017	13
2.3	Black Iron Pipe	10 ft.	90 ft.	100 ft.	15 amp	170921	127.5	No	No	0	12/19/2017	14
2.4	Black Iron Pipe	10 ft.	140 ft.	150 ft.	15 amp	170921	127.0	No	No	0	12/19/2017	15
2.5	Black Iron Pipe	10 ft.	190 ft.	200 ft.	15 amp	170921	127.0	No	No	0	12/19/2017	16
3.1	CounterStrike®	10 ft.	5 ft.	15 ft.	15 amp	1740	126.9	Yes	Yes	9	12/18/2017	1
3.2	CounterStrike®	10 ft.	40 ft.	50 ft.	15 amp	1740	127.4	Yes	Yes	11	12/18/2017	6
3.3	CounterStrike®	10 ft.	90 ft.	100 ft.	15 amp	1740	126.8	Yes	Yes	10	12/19/2017	19
3.4	CounterStrike®	10 ft.	140 ft.	150 ft.	15 amp	1740	126.9	Yes	Yes	8.5	12/19/2017	18
3.5	CounterStrike®	10 ft.	190 ft.	200 ft.	15 amp	1740	126.9	No	No	0	12/19/2017	17
4.1	FlashShield™	10 ft.	5 ft.	15 ft.	15 amp	1739	126.7	No	No	0	12/18/2017	3
4.2	FlashShield™	10 ft.	40 ft.	50 ft.	15 amp	1739	125.0	No	No	0	12/18/2017	8
4.3	FlashShield™	10 ft.	90 ft.	100 ft.	15 amp	1739	125.8	No	No	0	12/19/2017	25
4.4	FlashShield™	10 ft.	140 ft.	150 ft.	15 amp	1739	126.0	No	No	0	12/19/2017	24
4.5	FlashShield™	10 ft.	190 ft.	200 ft.	15 amp	1739	126.2	No	No	0	12/19/2017	23
5.1	WARDFlex® Max	10 ft.	5 ft.	15 ft.	15 amp	1723	126.7	Yes	Yes	9.5	12/18/2017	2
5.2	WARDFlex® Max	10 ft.	40 ft.	50 ft.	15 amp	1723	125.0	Yes	Yes	11.75	12/18/2017	7
5.3	WARDFlex® Max	10 ft.	90 ft.	100 ft.	15 amp	1723	125.8	Yes	Yes	11.75	12/19/2017	20
5.4	WARDFlex® Max	10 ft.	140 ft.	150 ft.	15 amp	1723	126.0	Yes	Yes	10	12/19/2017	21
5.5	WARDFlex® Max	10 ft.	190 ft.	200 ft.	15 amp	1723	126.2	Yes	Yes	9	12/19/2017	22

See Schematic on page 7 of 31 (Figure 9) where A, B, and C are described as A) wire length from switch to light, B) wire length from circuit breaker to switch, & C) wire length from cold water ground clamp on gas pipe to ground bus in circuit breaker panel.