Virginia Board of Housing and Community Development
CODES AND STANDARDS COMMITTEE
2015 CODE CHANGE CYCLE – BOOK 2 – PART 2
October 24, 2016

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Table R602.12.4
Required Length of Bracing Along Each Side of a Circumscribed Rectangle[a,b,c]

Wind Speed	Eave-to-Ridge Height (feet)	Number of Floor Levels Above[e,f]	Required Length of Bracing on Front/Rear Side (feet)								Required Length of Bracing on Left/Right Side (feet)							
			Length of Left/Right Side (feet)								Length of Front/Rear Side (feet)							
			10	20	30	40	50	60	70	80	10	20	30	40	50	60	70	80
~~90~~ 115	10	0	2.0	3.5	5.0	6.0	7.5	9.0	10.5	12.0	2.0	3.5	5.0	6.0	7.5	9.0	10.5	12.0
		1 [d]	3.5	6.5	9.0	12.0	14.5	17.0	19.8	22.6	3.5	6.5	9.0	12.0	14.5	17.0	19.8	22.6
		2 [d]	5.0	9.5	13.5	17.5	21.5	25.0	29.2	33.4	5.0	9.5	13.5	17.5	21.5	25.0	29.2	33.4
	15	0	2.6	4.6	6.5	7.8	9.8	11.7	13.7	15.7	2.6	4.6	6.5	7.8	9.8	11.7	13.7	15.7
		1 [d]	4.0	7.5	10.4	13.8	16.7	19.6	22.9	26.2	4.0	7.5	10.4	13.8	16.7	19.6	22.9	26.2
		2 [d]	5.5	10.5	14.9	19.3	23.7	27.5	32.1	36.7	5.5	10.5	14.9	19.3	23.7	27.5	32.1	36.7
	20	0	2.9	5.2	7.3	8.8	11.1	13.2	15.4	17.6	2.9	5.2	7.3	8.8	11.1	13.2	15.4	17.6
		1 [d]	4.5	8.5	11.8	15.6	18.9	22.1	25.8	29.5	4.5	8.5	11.8	15.6	18.9	22.1	25.8	29.5
		2 [d]	6.2	11.9	16.8	21.8	27.3	31.1	36.3	41.5	6.2	11.9	16.8	21.8	27.3	31.1	36.3	41.5
~~100~~ 130	10	0	2.5	4.0	6.0	7.5	9.5	11.0	12.8	14.6	2.5	4.0	6.0	7.5	9.5	11.0	12.8	14.6
		1 [d]	4.5	8.0	11.0	14.5	18.0	21.0	24.5	28.0	4.5	8.0	11.0	14.5	18.0	21.0	24.5	28.0
		2 [d]	6.0	11.5	16.5	21.5	26.5	31.0	36.2	41.4	6.0	11.5	16.5	21.5	26.5	31.0	36.2	41.4
	15	0	3.4	5.2	7.8	9.8	12.4	14.3	16.7	19.1	3.4	5.2	7.8	9.8	12.4	14.3	16.7	19.1
		1 [d]	5.2	9.2	12.7	16.7	20.7	24.2	28.2	32.2	5.2	9.2	12.7	16.7	20.7	24.2	28.2	32.2
		2 [d]	6.6	12.7	18.2	23.7	29.2	34.1	39.8	45.5	6.6	12.7	18.2	23.7	29.2	34.1	39.8	45.5
	20	0	3.8	5.9	8.8	11.1	14.0	16.2	18.9	21.6	3.8	5.9	8.8	11.1	14.0	16.2	18.9	21.6
		1 [d]	5.9	10.4	14.4	18.9	23.4	27.3	31.8	36.3	5.9	10.4	14.4	18.9	23.4	27.3	31.8	36.3
		2 [d]	7.5	14.4	20.6	26.8	33.0	38.5	44.9	51.3	7.5	14.4	20.6	26.8	33.0	38.5	44.9	51.3

For SI: 1 ft = 304.8 mm.

a. Interpolation shall be permitted; extrapolation shall be prohibited.

b. For Exposure Category C, multiply the required length of bracing by a factor of 1.20 for a one-story building, 1.30 for a two-story building, and 1.40 for a three-story building.

c. For wall height adjustments multiply the required length of bracing by the following factors: 0.90 for 8 feet (2438 mm), 0.95 for 9 feet (2743 mm), 1.0 for 10 feet (3048 mm), 1.05 for 11 feet (3353 mm), and 1.10 for 12 feet (3658 mm).

d. Where braced wall panels supporting stories above have been sheathed in wood structural panels with edge fasteners spaced at 4 inches (102 mm) on center, multiply the required length of bracing by 0.83.

e. A floor level, habitable or otherwise, contained wholly within the roof rafters or trusses shall not be considered a floor level for purposes of determining the required length of bracing.

f. A rectangle side with differing number of floor levels above shall use the greatest number when determining the required length of bracing.

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CTG-310.1 cdpVA-15

Proponent : Bob Torbin (bob.torbin@omegaflex.net)

2015 International Fuel Gas Code

310.1 Pipe and tubing ~~other than CSST.~~ Each aboveground portion of a gas *piping* system ~~other than corrugated stainless steel tubing (CSST)~~ that is likely to become energized shall be electrically continuous and bonded to an effective ground-fault current path. Gas *piping* ~~other than CSST~~ shall be considered to be bonded where it is connected to appliances that are connected to the *equipment* grounding conductor of the circuit supplying that *appliance*. Corrugated Stainless steel tubing (CSST) piping systems listed with an arc resistant jacket or coating system in accordance with ANSI LC-1 shall comply with this section. Where any CSST segments of a piping system are not listed with an arc resistant jacket or coating system in accordance with ANSI LC-1, Section 310.1.1 shall apply.

310.1.1 CSST~~.~~ without arc resistant jacket or coating system ~~Corrugated stainless steel tubing (~~
CSST~~)~~ gas *piping* systems and piping systems containing one or more segments of CSST not listed with an arc resistant jacket or coating system in accordance with ANSI LC-1 shall be bonded to the electrical service grounding electrode system or, where provided, the lightning protection grounding electrode system and shall comply with Sections 310.1.1.1 through 310.1.1.5.

2015 International Residential Code

G2411.1 (310.1) Pipe and tubing ~~other than CSST.~~ Each above-ground portion of a *gas piping system* ~~other than corrugated stainless steel tubing (CSST)~~ that is likely to become energized shall be electrically continuous and bonded to an effective ground-fault current path. *Gas piping* ~~other than CSST~~ shall be considered to be bonded where it is connected to *appliances* that are connected to the equipment grounding conductor of the circuit supplying that *appliance*. Corrugated stainless steel tubing (CSST) piping systems listed with an arc resistant jacket or coating system in accordance with ANSI LC-1 shall comply with this section. Where any CSST segments of a piping system are not listed with an arc resistant jacket or coating system in accordance with ANSI LC-1, Section G2411.1.1 shall apply.

G2411.1.1 (310.1.1) CSST without arc resistant jacket or coating system. ~~Corrugated stainless steel tubing (~~
CSST~~)~~ gas *piping* systems and piping systems containing one or more segments of CSST not listed with an arc resistant jacket or coating system in accordance with ANSI LC-1 shall be bonded to the electrical service grounding electrode system or, where provided, the lightning protection electrode system and shall comply with Sections G2411.1.1.1 through G2411.1.1.5.

Add new standard(s) as follows: ANSI LC-1-2014/CSA 6.26-2014 Fuel gas piping systems using corrugated stainless steel tubing

Reason:
The use of a CSST product with a protective, arc resistant jacket is an equivalent method of protection against electrical arcing damage caused by high voltage transient events such as lightning strikes. The protective jacket is designed to locally absorb and dissipate the arcing energy or conduct it away. The jacket, in essence, disrupts the focus of the arc and reduces the energy level below the threshold value that can cause a perforation of the tubing wall. This dynamic action is equally effective compared to the current CSST bonding method as confirmed by ICC ES PMG 1058. The protection against arcing is provided uniformly throughout the piping system, and is not affected by close proximity to other metallic systems that may not be similarly bonded.

The CSA Technical Sub-Committee for national consensus standard ANSI LC-1 (2014) added performance criteria for arc resistant jackets in 2014 which is why this standard reference was updated. These criteria provide the ability to determine if the CSST jacket can resist damage from transient arcing currents under conditions associated with lightning strikes. The ANSI LC-1 Standard defines the experimental means to determine whether the protective jacket provides resistance to damage from lightning strikes without the need for additional bonding as prescribed currently in G2411.1.1 of the 2015 edition of the International Residential Code and Section 310.1.1 of the International Fuel Gas Code. In addition, the ANSI LC-1 standard includes performance criteria for jacket wear/tear resistance, resistance to low temperature embrittlement, and resistance (of metallic components) to corrosion (when applicable). The ICC Evaluation Service has also performed an assessment of the arc resistant jacket technology, and has issued PMG listings for all three commercially available "black" CSST products.

In support of the 2015 edition of the NFPA 54 Code, extensive testing was performed under the management of the Gas Technology Institute to demonstrate the effectiveness of the prescribed method of bonding for CSST. That report was submitted and accepted by the NFGC Technical Committee in support of modifications made to the 2012 CSST bonding requirements. That same report (and test conditions) was used as the basis for a new study (performed by PowerCET) to examine the ability of the arc resistant jacket to provide the equivalent level of protection (or better) against arcing damage. That report is included with this proposal, and demonstrates that arc-resistant jackets will provide equal or better protection against lighting induced arcing as the bonding of standard CSST.

CSST with arc-resistant jacket has been commercially installed since 2004, and at the present time, three different (black-jacketed) products are commercially available. Field experience has been very favorable with over 125 million feet installed and only two confirmed cases of indirect or direct lightning damage to CSST piping systems using these black jackets. Currently, at least 15 states (as shown below) permit the installation of the arc resistant CSST without the need for additional bonding. Both conventional (yellow) and advanced (black) CSST products will continue to be commercially available and installed in new and existing buildings. Given that both methods of electrical protection of CSST systems have been demonstrated to be effective, they should be recognized and permitted in the Commonwealth of Virginia. The 2018 IFGC will include arc resistant CSST without the need for additional bonding when that language is extracted from the 2018 NFPA 54. We are asking that Virginia recognize those changes with the adoption of the 2015 IFGC.

States currently permitting black jacket CSST without additional bonding per Section 7.13.2:

Massachusetts	Oklahoma	Nebraska
Connecticut	Colorado	Montana
Rhode Island	New Jersey	Georgia
Wisconsin	North Dakota	Indiana
Michigan	Oregon	Maryland

Supporting Documentation:

http://media.iccsafe.org/cdpva/CSST_doc.pdf

Cost Impact: While arc-resistant CSST may cost 5-8 percent more per foot compared to conventional (yellow) CSST, there will be no negative cost impact to either the builder or the home owner. The additional cost of arc resistant CSST is offset by the savings associated with the cost of CSST bonding which includes two bonding clamps, 75-ft of #6 AWG copper conductor and the associated installation labor.

Workgroup Recommendation

Workgroup 4 Recommendation Recommendation: Consensus for Approval

Workgroup 4 Reason: 1st meeting: Torbin spoke on the code change proposal-Haywood asked about different fittings being used-Witt questioned language in NFPA 54 making it to the 2018 IFGC-Torbin stated will know in 2 weeks-Strausbaugh agreed
2nd meeting: consensus for approval

Workgroup 3 Recommendation Recommendation: Consensus for Approval

Workgroup 3 Reason: 1st meeting: Torbin not present-Dave Edler spoke for omegaflex-NFPA 54 committee has passed this up the ladder for approval for 2018 IFGC-LC1 should be followed by CSA6.6-Bartell asking why move forward until finalized with NFPA54-Gerber-field applied jacket? (No)
2nd meeting: consensus for approval

Board Decision

None

<u>Board Decisions</u>

- ☐ Approved
- ☐ Approved with Modifications
- ☐ Carryover
- ☐ Disapproved
- ☐ None

CTG-310.1 cdpVA-15

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EVALUATION OF INDIRECT LIGHTNING-CURRENT WITHSTAND OF COUNTERSTRIKE CSST

PREPARED BY

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22 DECEMBER 2014

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EVALUATION OF INDIRECT LIGHTNING-CURRENT WITHSTAND OF COUNTERSTRIKE CSST

EXECUTIVE SUMMARY

In response to concerns with the adequacy of electrical bonding of CSST gas piping systems, the National Fire Protection Association (NFPA) in 2009 instigated an investigation into the efficacy of direct bonding of such systems as a means of preventing lightning damage. This investigation led to the formation of a task group to assist the NFP 54 Fuel Gas Code Technical Committee. A report of the findings of this task group was provided to the NFPA 54 Technical Committee in May of 2013 followed by a presentation in June of 2013. The recommendations of the task force that direct bonding of CSST was effective at preventing damage from indirect lightning strikes was adopted by the NFPA Committee in 2013. The present study is an extension of that work and is intended to assess the equivalence of the use of arc-resistant CSST to indirect lightning strikes when indirectly bonded through appliances grounded to the electrical supply system and in the absence of a direct bonding conductor.

CounterStrike is the proprietary name of a flexible arc-resistant corrugated stainless steel tubing manufactured by Omega Flex, Inc. for fuel gas distribution. The product utilizes the same stainless steel tubing as traditional CSST, but encases the tubing in conductive plastic covering in place of the insulated plastic covering of the original product. The purpose of the conductive jacket is to provide protection of the steel tubing against electrical arcs, particularly those resulting from lightning discharges. The present report is an evaluation of the electrical withstand of CounterStrike to indirect lightning currents. This evaluation is based on laboratory measurements of the resistance of the jacket to arc damage from simulated lightning currents, measurements of the electrical parameters of the tubing and computer models to simulate the expected lightning currents for the defined scenarios used for the original NFPA study.

In recent high-current high-voltage laboratory tests, the variation of the susceptibility of CounterStrike to damage by electrical arcs of different durations has been found to confirm earlier preliminary data. The data are plotted as a curve of expected damage threshold versus total arc duration. This curve shows a minimum value of about 8 coulombs for arc durations of 15,000 microseconds (0.015 seconds), increasing to about 15 coulombs for the shorter arc durations of 3000 µs(0.003) seconds and greater than 20 C for arc durations of 1000 µs (typical of the standard double-exponential 10x350 µs test waveform). This arc resistance of CounterStrike may be compared to conventional (yellow-jacket) CSST, from which it is concluded that CounterStrike has fifty times the arc resistance of conventional CSST.

The electrical parameters of self-inductance and resistance of a 30-foot sample of ¾ inch diameter CounterStrike were measured in the laboratory, from which it was concluded that CounterStrike would behave similarly to other metallic conductors in conducting high-frequency lightning currents.

Computer simulations were run to predict the current magnitudes and waveshapes that would flow in an arc to the jacket of CounterStrike for scenarios in which indirect lightning currents were injected into a residence either on the incoming metallic gas line or electrical service. These scenarios were similar to those used for the earlier evaluation of the effectiveness of bonding in protecting conventional (yellow-jacket) CSST from indirect lightning events [1]. The present simulations eliminated the bonding conductor and assumed the CounterStrike was grounded only at an appliance. The simulations on CounterStrike were run with currents having a waveshape of 10x350 µs with a magnitude of 10 kA, as used in the original study.

It was concluded that, for the scenarios studied, the arc charge and duration would be insufficient to damage CounterStrike and that this result would be expected for simulated 10x350 µs lightning currents up to 50 kA, a magnitude that significantly exceeds all indirect lightning and includes a fraction of direct strikes.

INTRODUCTION

BACKGROUND

In response to concerns with the adequacy of electrical bonding of CSST gas piping systems, the National Fire Protection Association (NFPA) in 2009 instigated an investigation into the efficacy of direct bonding of such systems as a means of preventing lightning damage. This investigation led to the formation of a task group to assist the NFP 54 Fuel Gas Code Technical Committee.

In July 2010 an engineering firm in the lightning area, SEFTIM, was selected by the technical panel. SEFTIM's first task was to complete a literature review and develop a gap analysis to inform a future research project designed to validate installation methods for CSST gas piping to mitigate damage due to lightning events. This initial engineering review and gap analysis work is referred to as 'Phase I' of the project.

The SEFTIM report *Validation of Installation Methods for CSST Gas Piping to Mitigate Lightning Related Damage* (Phase I) was completed in April 2011. The executive summary of the report concludes with reference to the beneficial role of bonding metallic systems, but that there is a lack of sufficient information to validate installation methods of CSST gas piping to mitigate damage due to lightning events. The summary concludes with the need to perform a targeted testing program to gain greater information as a proposed Phase II of the project.

The project technical panel accepted SEFTIM's recommendation, and also selected SEFTIM to produce the Phase II Test Plan. SEFTIM produced the test plan, *Validation of Installation Methods for CSST Gas Piping to Mitigate Lightning Related Damage, Phase II, Proposal V2* (November 2011), and this test plan was also accepted by the project technical panel. In April 2012, the sponsors of the project, selected Gas Technology Institute (GTI), to manage the testing phase of the project as laid out in the SEFTIM Test Plan Phase II V2 (November 2011).

In October 2012, GTI presented a project update and initial findings to the NFPA 54 Technical Committee. GTI conducted further testing through December of 2012, and simulations in 2012 and early 2013. A report of the findings was provided to the NFPA 54 Technical Committee in May of 2013 followed by a presentation in June of 2013. The recommendations from this study were presented to the NFPA Technical committee in 2013 and were recommended for adoption in 2013.

PRESENT STUDY

CounterStrike is the proprietary name of a flexible arc-resistant corrugated stainless steel tubing manufactured by Omega Flex, Inc. for fuel gas distribution The product utilizes the same stainless steel tubing as the traditional (yellow-jacket) TracPipe, but encases the tubing in conductive plastic covering in place of the insulated plastic covering of the earlier standard product. The purpose of the conductive jacket is to provide protection of the steel tubing against electrical arcs, particularly those resulting from lightning discharges. This type of product is referred to generically as "Arc-Resistant CSST".

The present report covers an evaluation of the electrical withstand of CounterStrike to indirect lightning currents, based on measurements of the physical properties of the tubing and computer models to simulate the expected lightning currents for several defined scenarios. The objective of this report is to replicate the results of the previous study done with conventional CSST (when electrically bonded in accordance with the recommendations of the earlier GTI report), but with unbonded CounterStrike. This study evaluates CounterStrike's efficacy in resisting arc-damage from indirect lightning strikes when connected to a grounded appliance.

Details of lightning current waveforms used in the laboratory tests and for computer simulations are described in Appendix D.

ARC RESISTANCE OF CONVENTIONAL CSST

Arc damage has been observed to occur to conventional (insulated jacket) CSST tubing products, damage that is frequently ascribed to lightning discharges. When an electrical arc terminates on a metal surface, metal will be removed or displaced by a number of processes. The amount of metal removed or displaced depends on the energy dissipated in the arc/metal interface and its duration. The voltage of the arc is approximately constant, therefore, for a given waveshape, the energy is roughly proportional to the time integral of current, that is, the total electrical charge transfer. Many studies have confirmed that the size of hole created by electrical arcs in thin metals is closely proportional to the charge transfer for a given waveshape or duration of current.

The necessary charge to create a hole of a given size occurs for a current duration that has a minimum typically between about 0.01 and 0.1 seconds. This duration is of the same order of magnitude as the long-duration currents that occur in some lightning strikes as well as that of power frequency fault currents. In order to assess the likely damage from an electrical arc, the dependent variables that must be assessed are the magnitude of the current and its duration.

Duration represents the total time that the arc is present and was derived from work that used direct currents [3]. The duration of a double-exponential wave (typically used for lightning simulations) may be taken as approximately three times the time to half-value. This represents the time at which approximately 90% of the energy has been delivered by the wave. For example, the 10 kA 10x350 µs current wave used for these studies is shown in Fig. 1. The current waveform is the red curve with left vertical axis in kA and the cumulative charge waveform is the blue curve with right vertical axis in coulombs. This wave may be considered to have a total duration of 3x350 µs, which is 1,050 µs or 1.05 milliseconds. Test data shown on Fig. 2 use this criterion for the duration of double-exponential test waves.

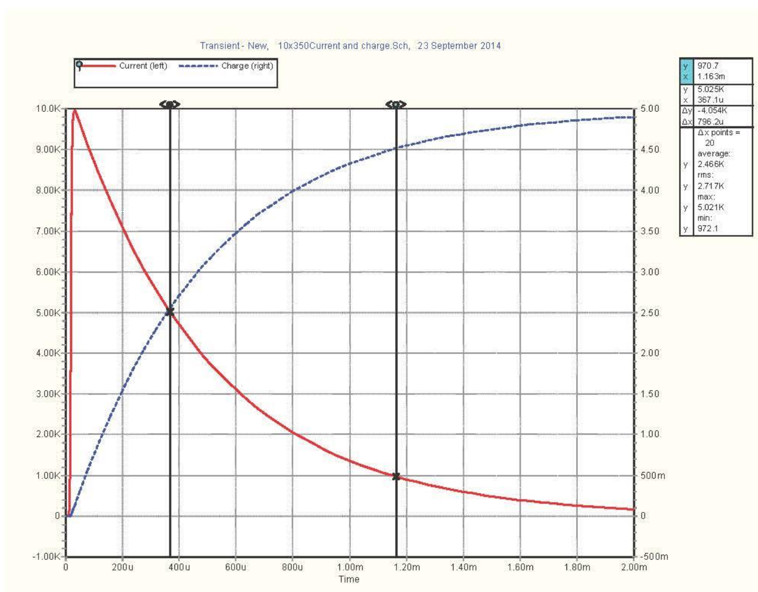

Fig. 1: Current and charge waveforms for the 10 kA 10x350 µs waveform

To assist with the evaluation of the likelihood of arc damage, the author has developed a set of susceptibility curves to describe the necessary charge to cause perforation in conventional CSST as a function of arc duration. These curves are based on an extrapolation of published curves from earlier testing work [2, 3, 4, and 5] together with more recent laboratory tests on CSST [6, 7, 8, 9, 10, and 11]. The latest susceptibility curves derived by the author for conventional (yellow jacket) CSST are shown in Fig 2.

Actual test data points for conventional CSST are shown for currents of 8x20 µs, 10x50 µs, 10x350 µs, and 19x543 µs waveshapes. Where a perforation was observed in testing, the data point is colored red, where no perforation occurred, the data point is colored green.

It can be seen that the data support the general shape of the curves, although there are too few data points for these curves to be determined more exactly, especially for very short-duration and very long-duration arcs. It can also be seen that experimental tests with the same charge and duration result in cases of both perforation and no perforation. This appears to be a result of the quite wide variance of test data, which has been widely reported by other investigators. This variance led to the two curves shown in Fig. 2. The upper (red) curve shows the limits above which arc damage is likely, the lower (green) curve shows the limits below which arc damage is unlikely. The region between the curves describes a zone where arc damage is possible.

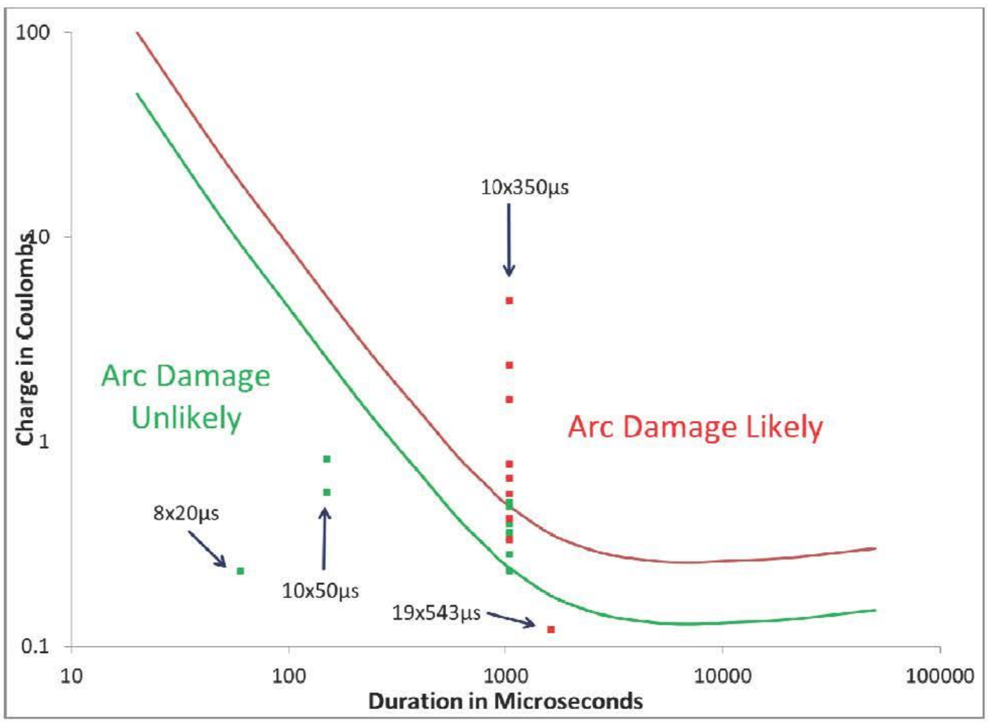

Fig. 2: Arc charge versus duration required to damage conventional CSST

ARC RESISTANCE OF COUNTERSTRIKE

CounterStrike provides its arc-resistance property by dissipating the electrical energy of an arc over a larger surface area of the metal surface through the conductive jacket, significantly reducing metal displacement at the arc location. This process has been verified by laboratory testing with simulated lightning currents of various magnitudes and durations. In these laboratory tests, the dissipation of the electrical current over significant portions of the jacket is clearly evident (Fig. 3). In some cases, the conductive jacket is punctured or ruptured by the arc (Fig. 4) but nevertheless protects the metal tubing from arc damage.

Although this process may be significantly different from that occurring on a purely metal surface, the general physical processes that result in more energy being required to perforate the tubing for very short-duration arcs and very long-duration arcs are somewhat similar. Consequently, for the initial assessment of the arc-resistance of CounterStrike, it will be assumed that its behavior is similar to that of a metal of greater thickness than standard CSST, with a minimum required charge occurring with arc durations of between 0.01 and 0.1 seconds. Based on recent test data [8], the minimum charge to perforate CounterStrike using 12x3000 μs waves was found to be between 5 and 6 coulombs. This would suggest that the arc-resistance of CounterStrike is not too different from that of metal of thickness around 80 mils (seven to eight times thicker than regular CSST). Based on prior arc-puncture testing on metals of this thickness [2], approximate preliminary charge/time curves can be calculated and are shown in Fig. 5.

Fig. 3: Laboratory testing of CounterStrike with simulated lightning currents

Fig. 4: High-current arc damage to jacket with undamaged tubing

Also shown on Fig. 5 are calculated points that represent the transferred charge and duration for the standard 10x350 μs waveform that is used to represent lightning at levels of 10 kA, 25 kA and 50 kA. The 10 kA 8x20 μs wave used for some indirect lightning currents has a charge that lies below the minimum level of the chart and is not shown.

The 10 kA 10x350 μs wave was used in the earlier simulation scenarios [1] to represent indirect lightning by the partial transfer of direct lightning currents into a building on the incoming services. This is a fairly long-duration waveform and the 10 kA magnitude for indirect events is considered conservative. The 50 kA 10x350 μs waveform may be considered representative of a fairly severe direct stroke lightning current.

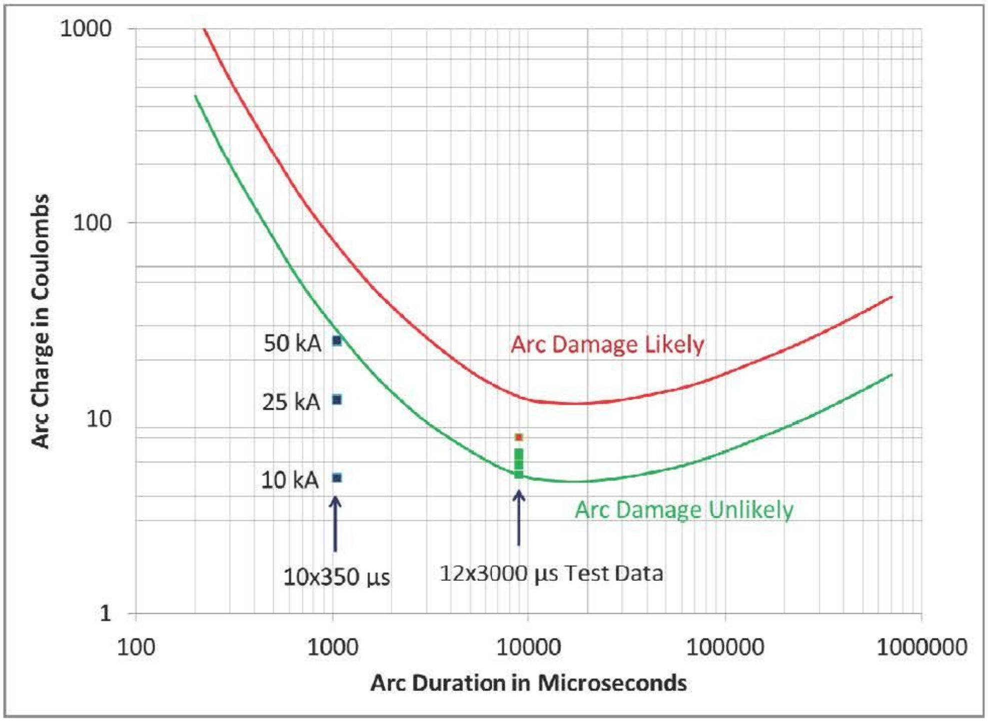

Fig. 5: Arc charge versus duration required to damage CounterStrike (preliminary)

It should be noted from the susceptibility curves shown in Fig. 5 that the arc withstand capabilities of CounterStrike greatly exceeds all the indirect lightning scenarios (10 kA, 10x350 µs), having been directly laboratory tested with this waveshape at up to 22 kA (12 C). This increased arc resistance enables CounterStrike to withstand many direct strike scenarios (possibly exceeding 50 kA 10x350 µs).

More recent laboratory test data extended the arc susceptibility measurements of CounterStrike with lightning test waveforms of 10x350 µs, 10x1000 µs, 10x2840 µs and 10x4000 µs. The results of these tests for ½-inch CounterStrike are shown in Fig. 6 and for 1-inch CounterStrike in Fig. 7, together with the estimated damage threshold curves.

It can be seen that the new data confirm that the arc resistance of CounterStrike is not only substantially higher than TracPipe, but also follows a similar trend in requiring higher magnitudes of charge to cause damage when arc duration is shorter.

Damage to CounterStrike using 10x350 µs waves was never achieved during laboratory tests since the required levels exceed the capabilities of the surge generator, but a minimum level of 25 coulombs for this wave appears consistent with the test data.

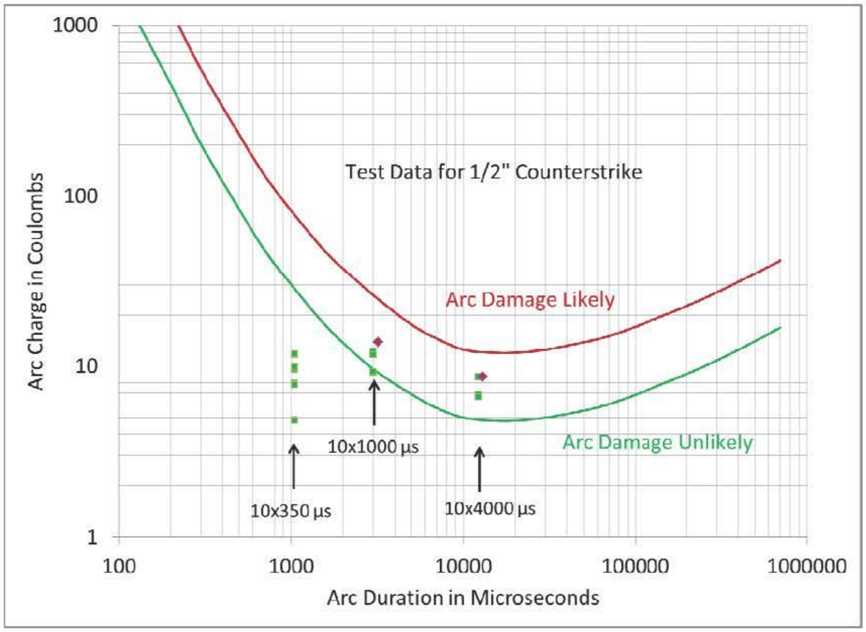

Fig. 6: Arc charge versus duration required to damage ½" CounterStrike

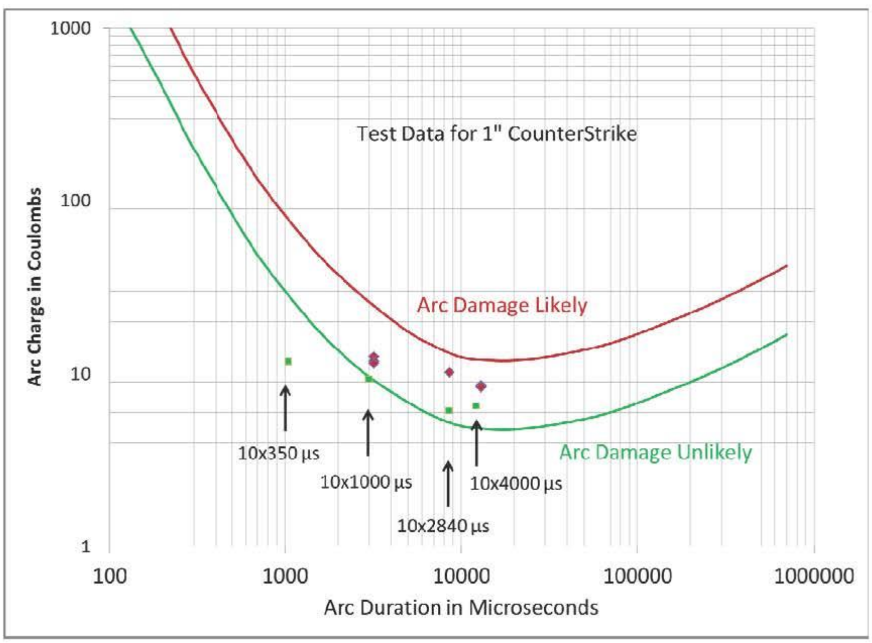

Fig. 7: Arc charge versus duration required to damage 1" CounterStrike

SELF-INDUCTANCE

In order to calculate the distribution of current and voltage on an installation involving CounterStrike, it is necessary to have a reasonably accurate estimate of its electrical self-inductance and resistance of any length involved. These characteristics of conventional CSST have been recently measured by the author [1]. The result of these measurements was that the self-inductance can be calculated using standard formulae using the radius of the conductor as one half of its maximum diameter and that the high-frequency resistance is equivalent to that measured at low frequencies.

The self-inductance of conventional CSST was measured on a two-turn circular loop of the material using a commercial precision LCR meter (Agilent) and the resistance assessed by measuring the voltage drop created by a 1-amp direct current around the loop.

This procedure was repeated for a sample of CounterStrike having a nominal internal diameter of ¾ inch. Using a 30-foot length of the tubing, the two-turn loop was measured to have a diameter of 4 feet 10 inches (1.48 meters). The CounterStrike tubing outside diameter was measured at 1.5 inches (38 mm). The self-inductance of the two-turn loop was measured using the Agilent LCR meter at a frequency of 10 kHz and was found to be 13.95μH. The standard formula (Appendix B) predicts that the self-inductance of a two-turn loop with a loop radius of 2 feet 5 inches (0.74 m) and tubing radius of 0.75 inches (19 mm) is 13.92μH. The difference between the measured and theoretical values is insignificant and again confirm that the standard formulae may be used, taking the radius as half the outside diameter.

RESISTANCE

The resistance of the nominally 30-foot loop of CounterStrike was assessed by measuring the voltage drop created by an applied 1-amp direct current and found to be 0.50 ohms. A 3-feet 5 inch (1.04 meter) long section of the conductive jacket was removed from the sample of CounterStrike and its resistance measured using the Agilent LCR meter at 1 kHz and found to be 7.4 ohms, or 2.2 ohms per foot (7.1 ohms per meter). The expected resistance of a 30-foot length of the metal tubing from prior measurements on standard CSST is 0.53 ohms. The resistance of a 30-foot length of jacket is approximately 66 ohms, leading to an estimated overall resistance of the jacketed product of 0.52 ohms, close to the measured value of 0.50 ohms.

From these resistance measurements, it may be concluded that the behavior of the material in conducting electricity along the length of the tubing is affected very little by the presence of the conductive jacket, which has a much higher resistance than the metal tubing itself.

PARAMETERS FOR SIMULATIONS

The above measurements confirm the earlier ones that show that the self-inductance of CSST may be computed using standard (Rosa) formulae using the maximum diameter of the tubing. For CounterStrike, this maximum diameter may be taken as that of the external conductive jacket.

The electrical resistance of CounterStrike is slightly lower than that of comparable CSST provided with an insulating jacket.

INDIRECT STRIKE SCENARIOS SIMULATED

Three scenarios were initially developed as part of the original SEFTIM/NFPA study on the benefits of bonding CSST to mitigate arc damage from indirect lightning surges [1] (Appendix C). These scenarios described simplified installations of fuel gas piping and electrical wiring in a residence. Of these, only Scenario 2 was considered fully applicable to a CounterStrike installation. Scenario 2 was also expanded to include the alternative injection of lightning current at the electrical service entrance to give a modified Scenario 3. These are now referred to as Indirect Strike Scenario1 (Fig. 8) and Indirect Scenario 2 A (Fig. 9) respectively. Replacement of the incoming metallic gas pipe with a plastic non-conducting pipe (considered more representative of present installation practice) was simulated in Scenario 2B (Fig. 10).

The point of simulated arc-attachment is at the mid-point of a 100-foot (30 m) length of CounterStrike. The CSST is connected to a manifold, from which a second 16-foot (5m) length of CounterStrike feeds an appliance, which it is electrically grounded to the electrical service. This connection provides the minimum safety bonding of gas piping systems required in residences by the National Electrical Code (Section 250.104 B).

The current magnitude and waveforms in the arc to the CounterStrike jacket, the ground connected to the CSST at the appliance were measured for indirect lightning currents of 10 kA with the standard 10x350 μs waveform. In the original simulations, a 30 kV flashover voltage was assumed between the grounded object and the CSST. For the CounterStrike simulations, this voltage is assumed to be zero (direct contact). This assumption results in slightly higher charge transfer to the CounterStrike and may be regarded as a conservative assumption.

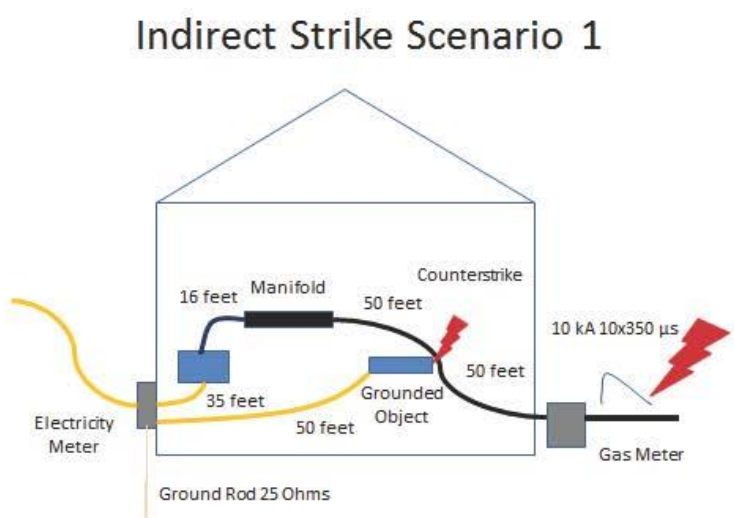

Fig 8: Indirect Strike Scenario 1

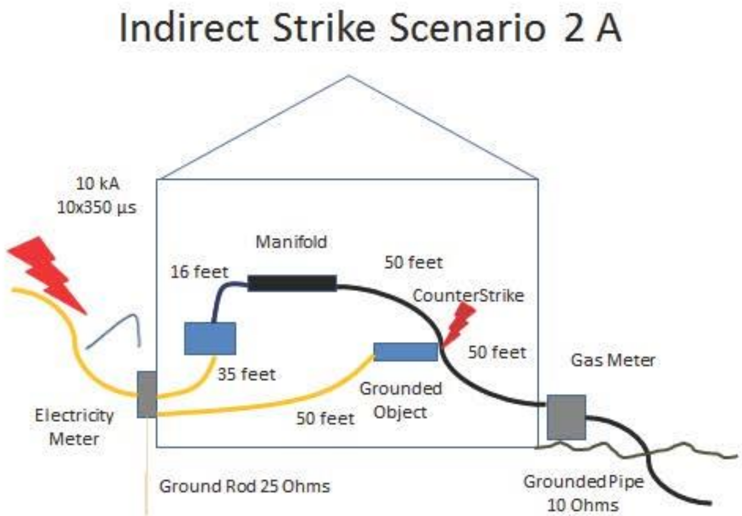

Fig. 9: Indirect Strike Scenario 2 A

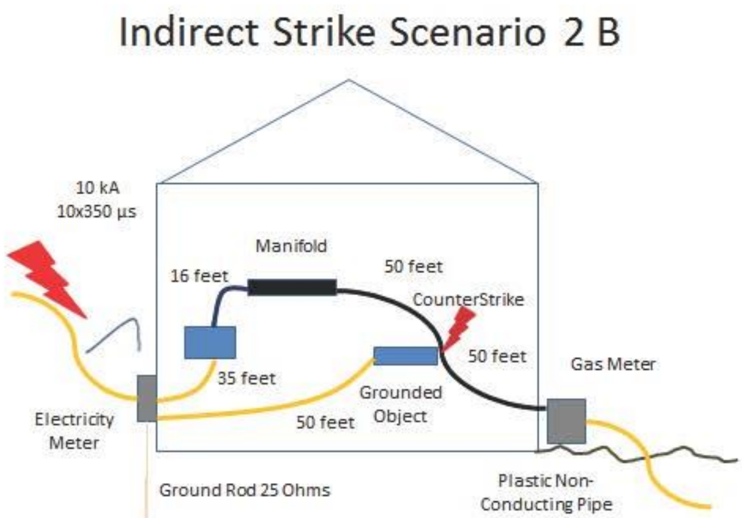

Fig. 10: Indirect Strike Scenario 2 B

Three further scenarios (Figs 11, 12 and 13) were also studied based on the second simulations done as part of the original CSST bonding validation study.

These scenarios are somewhat similar to the first three except that the gas system is connected to an attic-mounted HVAC system and contact with the jacket occurs 10-feet from this equipment. The grounding conductor of the power supply to this unit provides the required bonding for the CounterStrike.

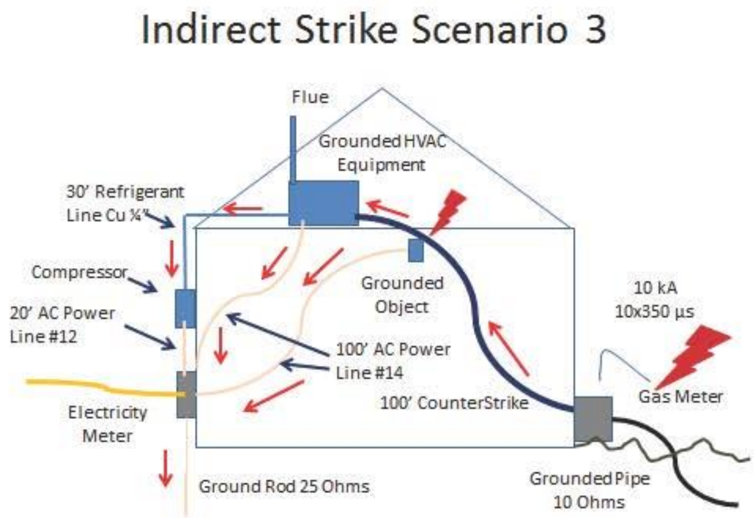

Fig. 11: Indirect Strike Scenario 3

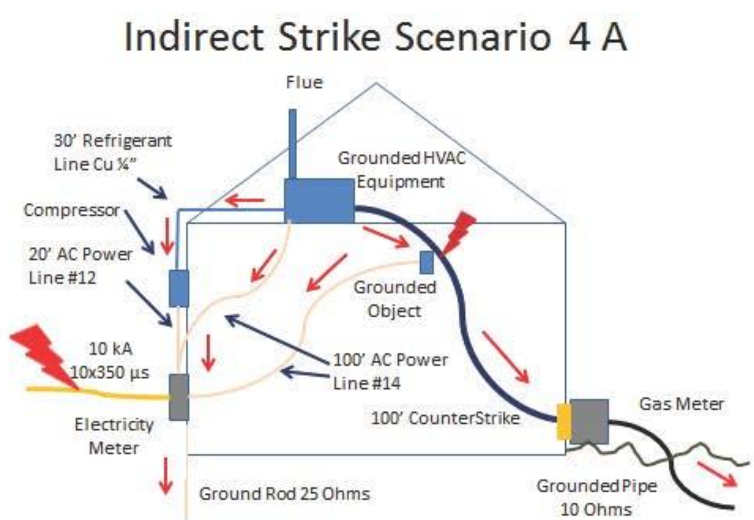

Fig. 12: Indirect Strike Scenario 4 A

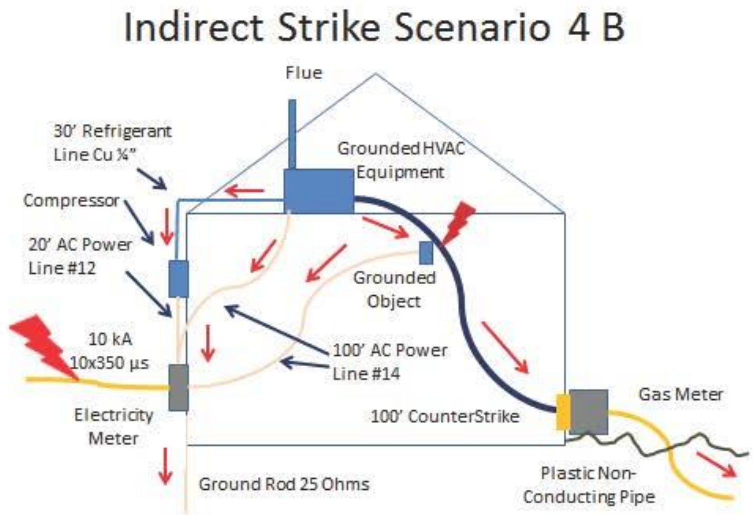

Fig. 13: Indirect Strike Scenario 4 B

INDIRECT STRIKE SCENARIO 1

The computed waveshapes for Scenario 1 are shown in Fig. 14 for a current of 10 kA, 10x350 µs injected on the incoming gas service at the meter.

In this scenario, the only path for the lightning current into the building is along the gas pipe. The lightning current divides at the point of contact between the CounterStrike and grounded object, but in this scenario this is the lowest impedance path and the majority of the lightning current flows through the arc to the jacket. The charge computed through the arc is nearly 4.5 C and 90% of this is delivered in about 1.1 milliseconds.

From the data shown in Figs. 6 and 7, the arc withstand of CounterStrike for these conditions is likely above 25 C, so no damage is expected.

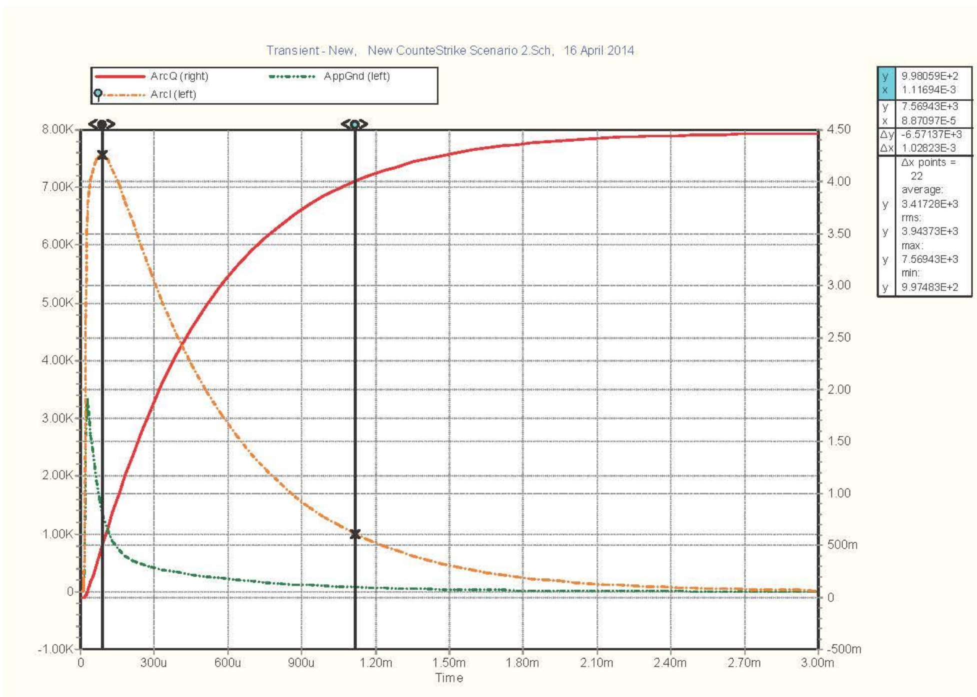

Fig. 14: Scenario 1 calculated waveshapes for 10kA 10x350µs

The continuous red line shows the calculated charge transfer in the arc to the CounterStrike

The dotted red line shows the calculated current in the arc to the CounterStrike

The dotted green line shows the calculated current in the ground

INDIRECT STRIKE SCENARIO 2 A

The computed waveshapes for Scenario 2 A for a 10kA 10x350µs wave injected at the electrical service entrance with a buried metallic gas service pipe are shown in Fig. 15.

In this scenario, a substantial portion of the lightning current flows to the electrical service ground, with the other fraction flowing along the gas line. This fraction further divides at the arc contact point, with some current flowing to earth through the buried gas line and another portion flowing through the arc to the grounded object. The charge computed in the arc for this scenario is just over 3 C and again 90% of this charge is delivered in about 1.1 milliseconds.

From the data shown in Figs. 6 and 7, the arc withstand of CounterStrike for these conditions is likely above 25 C, so no damage is expected.

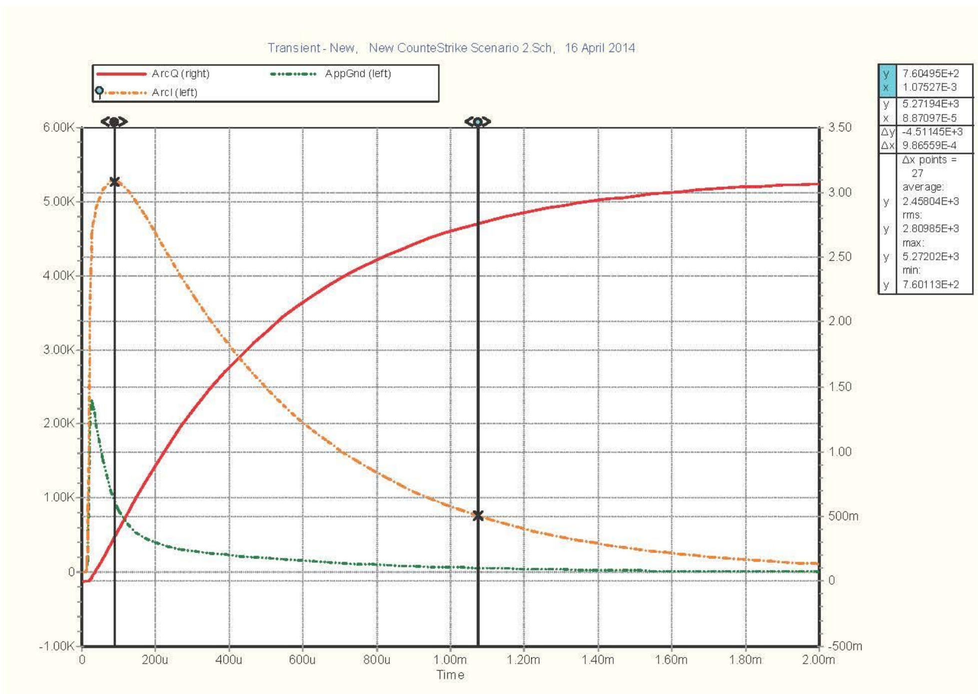

Fig. 15: Scenario 2 A calculated waveshapes 10kA 10x350µs, metallic gas service

The continuous red line shows the calculated charge transfer in the arc to the CounterStrike

The dotted red line shows the calculated current in the arc to the CounterStrike

The dotted green line shows the calculated current in the ground

INDIRECT STRIKE SCENARIO 2 B

The computed waveshapes for Scenario 2 B for a 10kA 10x350μs wave injected at the electrical service entrance with a plastic non-conducting gas service pipe are shown in Fig. 16. In this scenario, there is no significant current flow through the CounterStrike jacket.

From the data shown in Figs. 6 and 7, the arc withstand of CounterStrike for these conditions is likely above 25 C, so no damage is expected.

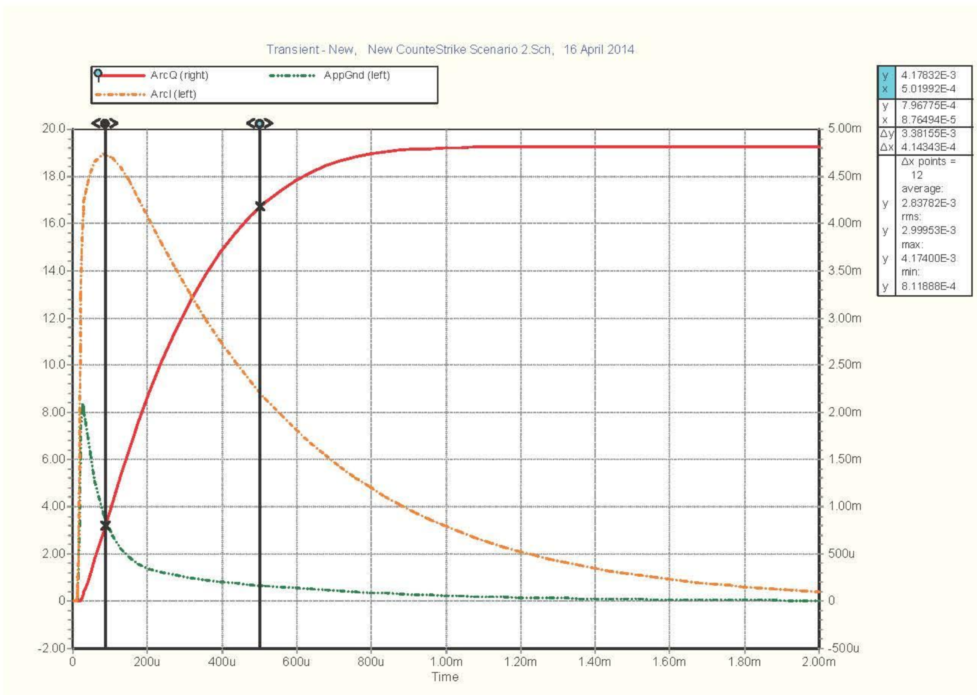

Fig. 16: Scenario 2 B calculated waveshapes 10kA 10x350μs, plastic gas service

The continuous red line shows the calculated charge transfer in the arc to the CounterStrike

The dotted red line shows the calculated current in the arc to the CounterStrike

The dotted green line shows the calculated current in the ground

INDIRECT STRIKE SCENARIO 3

The computed waveshapes for Scenario 3 for a 10 kA, 10x350 μs wave injected on the incoming gas service are shown in Fig. 17. The arc current reaches a peak of just under 1 kA and deposits a total charge of about 0.4 C, with the time to 90% being about 900 μs.

From the data shown in Figs. 6 and 7, the arc withstand of CounterStrike for these conditions is likely above 25 C, so no damage is expected.

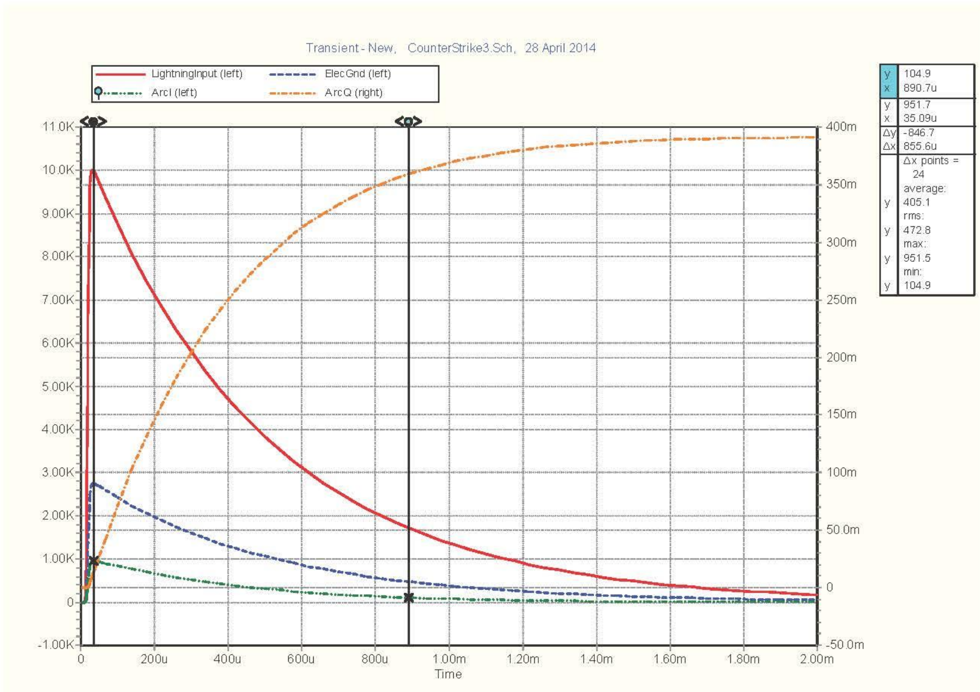

Fig. 17: Scenario 4 A calculated waveshapes 10kA 10x350μs, metallic gas service

The continuous red line shows the lightning input waveform

The dotted red line shows the calculated charge transfer in the arc to the CounterStrike

The dotted green line shows the calculated current in the arc to the CounterStrike

The dotted blue line shows the calculated current in the electrical service ground

INDIRECT SCENARIO 4 A

The computed waveshapes for Scenario 4 A for a 10 kA, 10x350 µs wave injected on the incoming electricity service are shown in Fig.18. The arc current reaches a peak of about 2.4 kA and deposits a total charge of about 1.0 C, with the time to 90% being about 800 µs.

From the data shown in Figs. 6 and 7, the arc withstand of CounterStrike for these conditions is likely above 25 C, so no damage is expected.

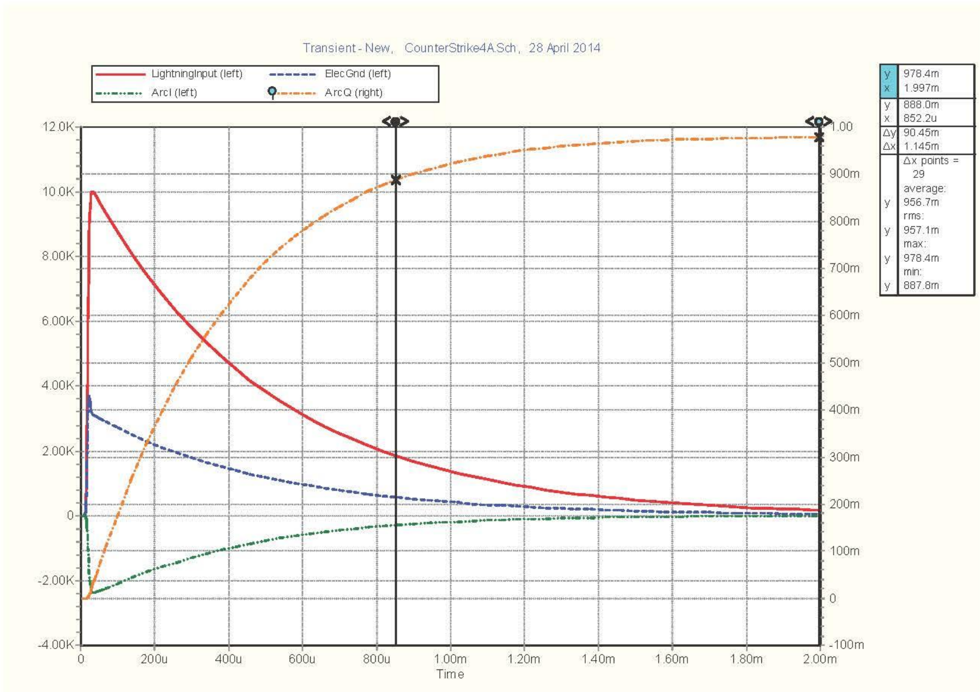

Fig. 18: Scenario 4 A calculated waveshapes 10kA 10x350µs, metallic gas service

The continuous red line shows the lightning input waveform

The dotted red line shows the calculated charge transfer in the arc to the CounterStrike

The dotted green line shows the calculated current in the arc to the CounterStrike

The dotted blue line shows the calculated current in the electrical service ground

INDIRECT SCENARIO 4 B

The computed waveshapes for Scenario 4 A for a 10 kA, 10x350 µs wave injected on the incoming electricity service are shown in Fig. 19. The arc current reaches a peak of just 9 A, with insignificant charge transfer to the CounterStrike jacket.

From the data shown in Figs. 6 and 7, the arc withstand of CounterStrike for these conditions is likely above 25 C, so no damage is expected.

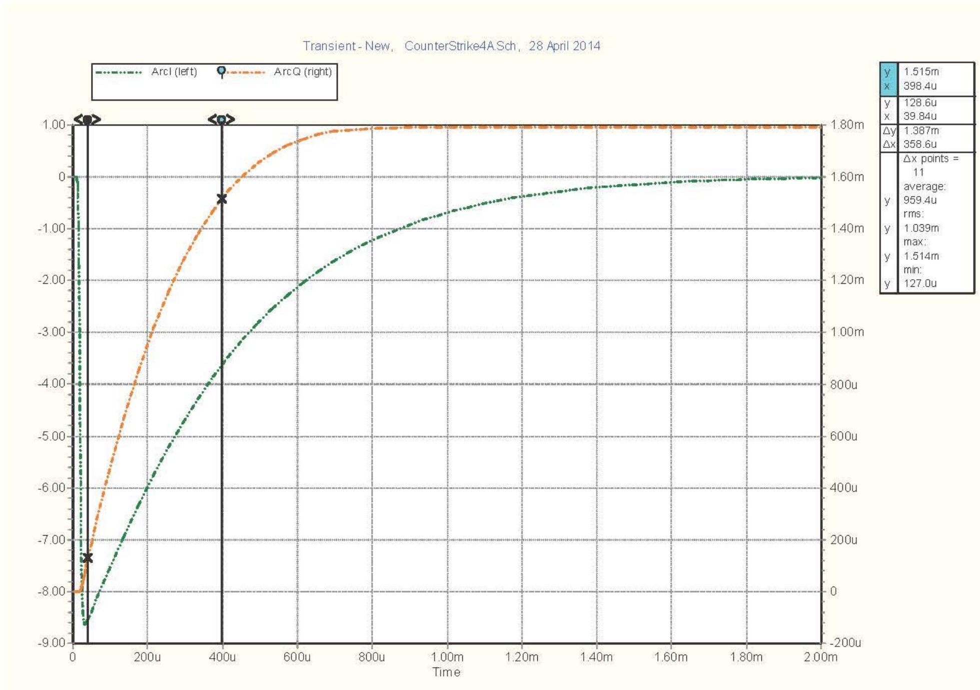

Fig. 19: Scenario 4 B calculated waveshapes 10kA 10x350µs, plastic gas service

The dotted red line shows the calculated charge transfer in the arc to the CounterStrike

The dotted green line shows the calculated current in the arc to the CounterStrike

SUMMARY OF SIMULATION RESULTS

Indirect Strike Scenario	Arc Current	Arc Duration	Arc Charge	CounterStrike Damage Threshold
1 (Metal Gas Service)	7.6 kA	1.1 ms	4.5 C	~25 C
2 A (Metal Gas Service)	5.3 kA	1.1 ms	3.1 C	~25 C
2 B (Plastic Gas Service)	19 A	0.5 ms	~ 0.1 C	~25 C
3 (Metal Gas Service)	950 A	0.9 ms	0.4 C	~ 25 C
4 A (Metal Gas Service)	2.4 kA	0.8 ms	1.0 C	~ 25 C
4 B (Plastic Gas Service)	9 A	0.4 ms	0.0 C	~ 25 C

Table 1: Summary of simulation results

DISCUSSION OF COUNTERSTRIKE SIMULATIONS

As already noted, the input lightning current selected for the original CSST bonding study [1] was 10 kA with a double-exponential waveshape of 10x350 µs, which is generally regarded as rather severe for exposure of building services to indirect or partial direct lightning currents. This wave delivers a total electric charge of about 5 coulombs in a time of just over 1 millisecond and appears incapable of rupturing CounterStrike, even if the total charge were to be discharged through a single arc to the jacket. Indeed, it appears from Fig. 5 that CounterStrike may be able to withstand arc discharges having a waveshape of 10x350 µs at currents of up to 50kA (charge of 25 coulombs) without damage. This magnitude likely covers not only all indirect scenarios but also a significant portion of direct strikes also.

Simulation results of scenario 1 show a large part of the incident lightning current deposited through the arc to the CounterStrike jacket, with a total charge transfer computed at 4.5 coulombs. Simulation results of scenario 2 A show rather less current and charge through the arc, but a still significant 3.1 coulombs. The simulation result of scenario 2 B shows an insignificant current flow through the arc to the CounterStrike jacket. The simulation results of scenario 3 show a modest charge transfer of 0.4 coulombs. The results of simulation 4A show about one fifth of the lightning charge through the arc, or 1.0 coulombs. Similarly to the results of the simulation of scenario 2 B, replacement of a buried metal gas service with an insulating plastic pipe in scenario 4 B dramatically lowered the current and charge flow to the CounterStrike.

These simulations show that the presence of a grounded metallic gas service that is not electrically bonded to the electrical service ground significantly increases current flow from indirect lightning currents entering on the electric utility and exacerbates damage in such cases where an arc occurs to gas tubing. However, it should be noted that plastic pipes are now being used for buildings of new construction and such services will become predominant.

These data points from Table 1 are shown with the arc susceptibility curves developed for CounterStrike in Fig. 20. All three simulation calculated arc charge/duration points lie below the lower (green) susceptibility curve, suggesting that no arc damage would occur. The data point for Scenario 2B is not shown as it was far below the plotted ranges.

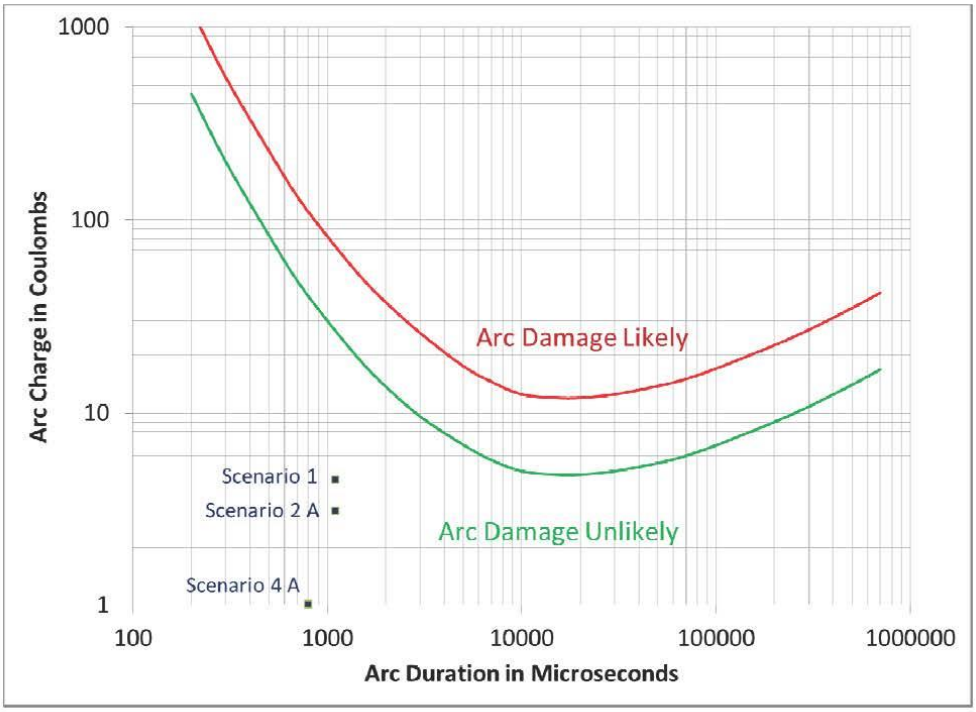

Fig. 20: Arc susceptibility curves for CounterStrike with simulation data

COMPARISON WITH BONDED TRACPIPE SIMULATIONS

The comparative performance of TracPipe (insulated yellow jacket) CSST with CounterStrike (conducting jacket) is of interest, particularly for installations in which CounterStrike is grounded only through connected equipment and not with a direct bonding conductor as used for TracPipe installations.

To compare these, the original simulations 1 and 2 for TracPipe equipped with a 75 foot #6 bonding conductor were compared with a similar installation in which CounterStrike was grounded only indirectly through electrical equipment. The configuration of these simulations is similar to those shown in Figs. 9 and 10.

As expected, without the bond, significantly larger currents and charge flowed through the simulated arc to the CSST, approaching the full 5 coulombs of the incident lightning current. With a 75 foot bonding conductor, arc currents were computed to be both significantly smaller in magnitude and shorter in duration. In both cases, the expected charge transferred through the arc to the CSST was well below the threshold of damage for the particular CSST product. These data points are illustrated in Fig. 21.

These data may also be interpreted by the ratio between the incident arc charge and the expected threshold of susceptibility of the CSST, which gives a measure of the safety factor. These are shown for the two scenarios for Bonded TracPipe and Unbonded CounterStrike in Table 2.

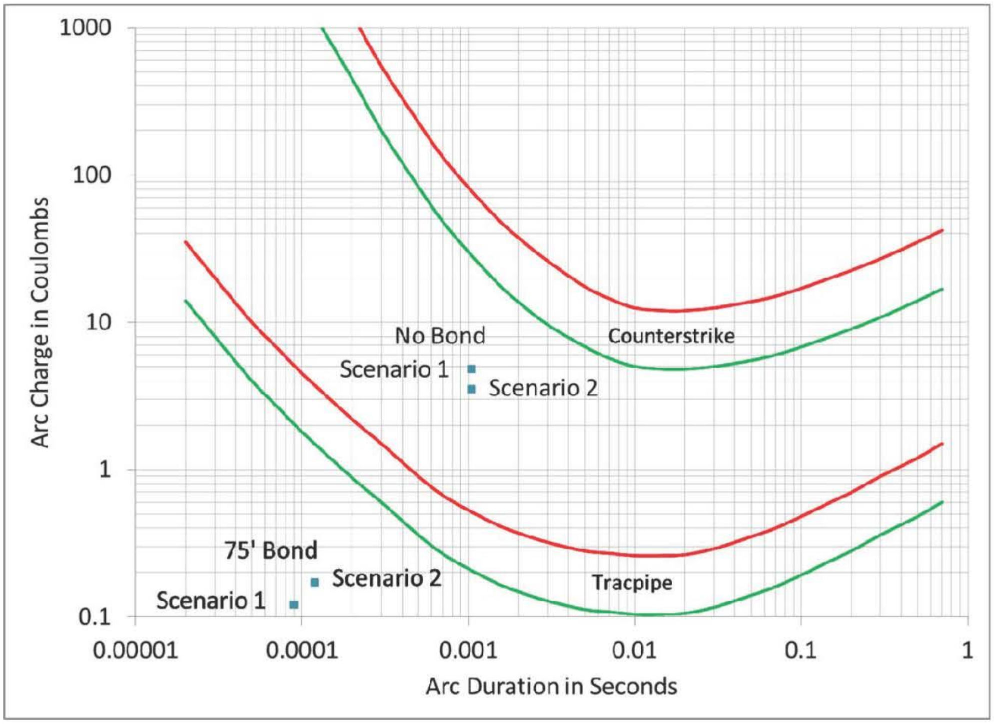

Fig. 21: Comparison between Indirect Strike Performances of Bonded TracPipe with Unbonded CounterStrike

Scenario	Arc Charge	Duration	CSST Withstand	Safety Factor
# 1 Bonded TracPipe	0.12	.00009	2.0	16.7
#2 Bonded TracPipe	0.17	.00012	1.5	8.8
#1 Unbonded CounterStrike	4.8	.0011	30	6.3
#2 Unbonded CounterStrike	3.5	.0011	30	8.6

Table 2: Comparison of Safety Factor between Bonded TracPipe and Unbonded CounterStrike

CONCLUSIONS

The laboratory measurements of electrical self-inductance and resistance of CounterStrike CSST show it to have similar characteristics to other metallic conductors when subjected to impulsive lightning currents.

Experimental measurements of the arc resistance of CounterStrike when subjected to simulated lightning currents show that it has more than fifty times the arc-resistance of conventional CSST.

Simulations of the expected distribution of lightning current for installation scenarios developed initially for the evaluation of the effectiveness of bonding for protecting conventional CSST against indirect lightning strikes [1] were adapted to evaluate CounterStrike. These simulations show that CounterStrike will be immune from the effects of indirect lightning at the 10 kA levels with the 10x350 µs waveform used for this evaluation and likely will survive impressed currents of up to 50 kA and arc charges of up to 25 coulombs. These are severe levels more consistent with the effects of direct lightning strikes than the lower energy indirect events.

For these indirect strike scenarios, it may be concluded that CounterStrike will be immune from lightning damage, even if it is bonded only indirectly through the grounding conductor of the electrical equipment to which it is connected.

Comparison between the performance of TracPipe equipped with a bonding conductor and CounterStrike grounded only indirectly through electrical equipment shows large and comparable safety margins. The performance of both is expected to be similar.

It should finally be noted that the scope of this report is limited to the effects of lightning on gas tubing and is not intended to be a comprehensive study of the effects of lightning on the gas and electrical services in buildings or the safety of gas systems in general. Furthermore, this study pertains to the individual tubing components of a gas supply system and not to the whole system. Lightning damage to the other components of a gas supply system, including appliance connectors, control valves, pressure regulators and similar devices is possible. A full analysis of the safety of gas piping systems, whether rigid steel pipe or flexible tubing, would require further comprehensive study.

Michael F. Stringfellow

Michael F. Stringfellow 22 December 2014

Chief Scientist

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11. B. Kraft & R. Torbin, "Effectiveness of Direct Bonding of Gas Piping in Mitigating Damage from an Indirect Lightning Flash, report for Titeflex Corp, 2007

APPENDIX A

COMPUTER SIMULATION MODELS

SCENARIO 1

The computer model used for Scenario1 is shown in the schematic below. The 10 kA, 10x350 µs indirect lightning current is applied at the gas meter.

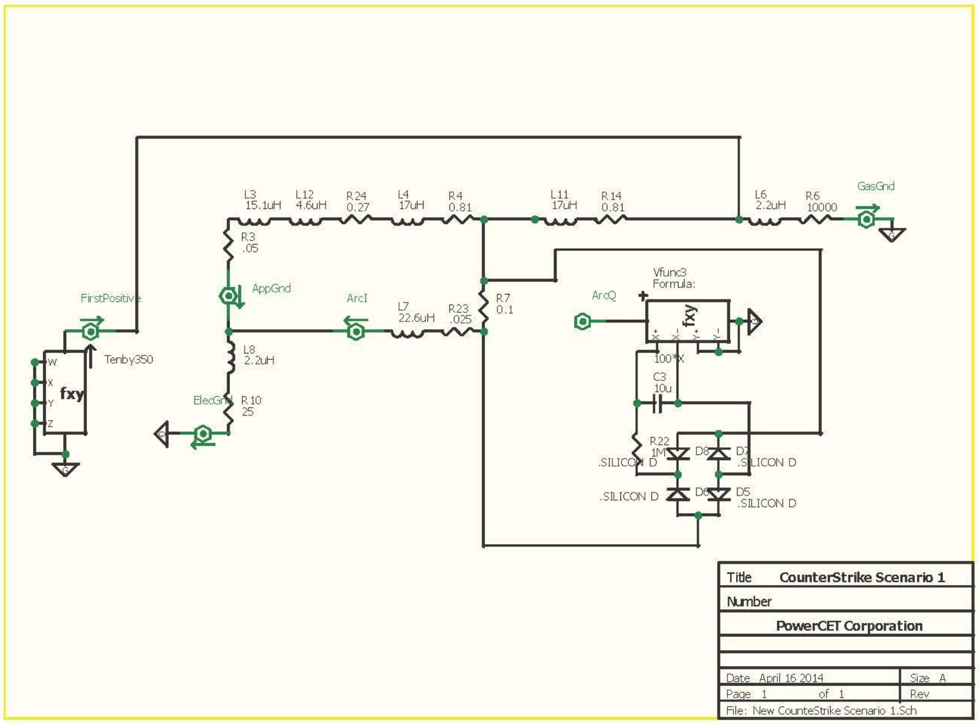

Fig. A1: Scenario 1 simulation model

SCENARIO 2

The computer model used to simulate Scenario 2 is shown in the schematic below. The 10 kA, 10x350 µs indirect lightning current is applied at the electric service entrance. The incoming gas service is simulated as plastic by increasing the grounding resistance R6 from 10 ohms to 10,000 ohms.

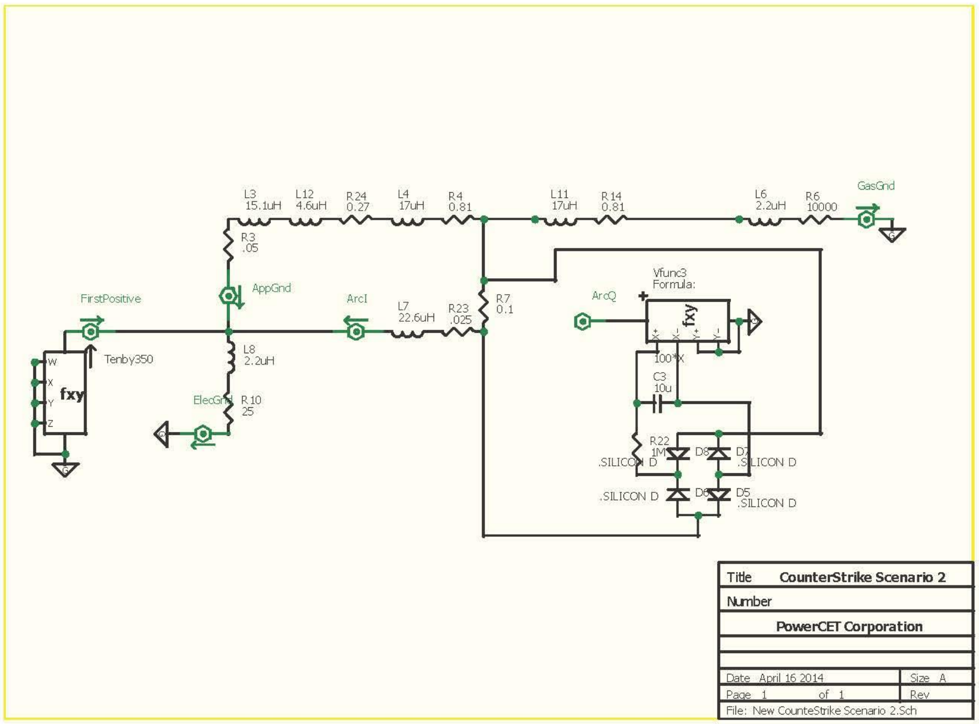

Fig. A2: Scenario 2 simulation model

The computer model used for Scenario 3 is shown in the schematic below. The 10 kA, 10x350 μs indirect lightning current is applied at the gas meter.

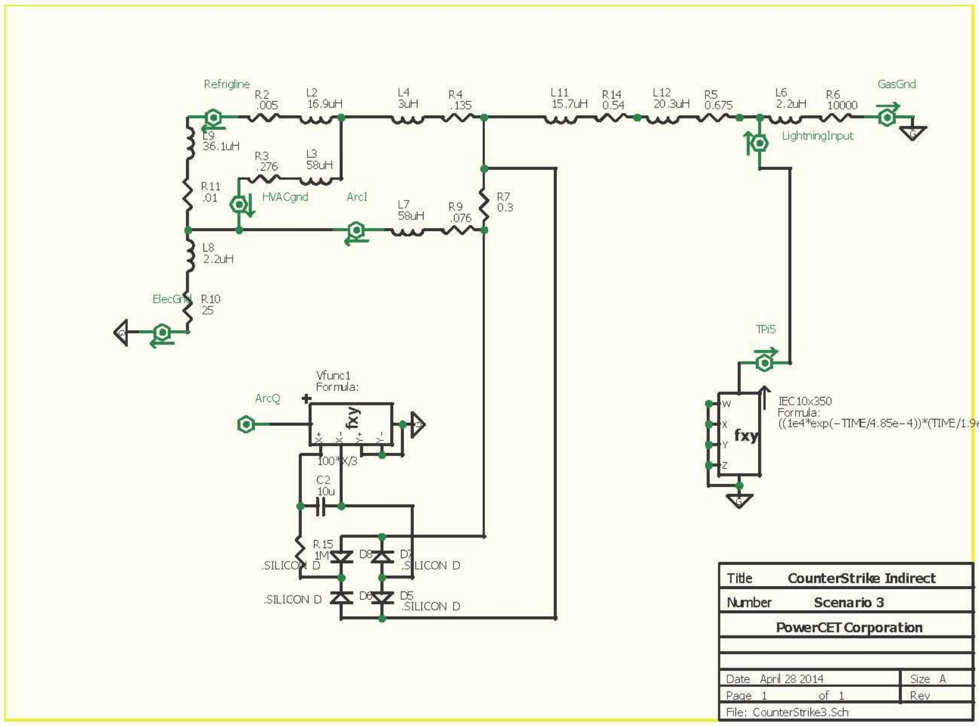

Fig. A 3: Scenario 3 simulation model

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SCENARIO 4

The computer model used to simulate Scenario 4 is shown in the schematic below. The 10 kA, 10x350 µs indirect lightning current is applied at the electric service entrance. The incoming gas service is simulated as plastic by increasing the grounding resistance R6 from 10 ohms to 10,000 ohms.

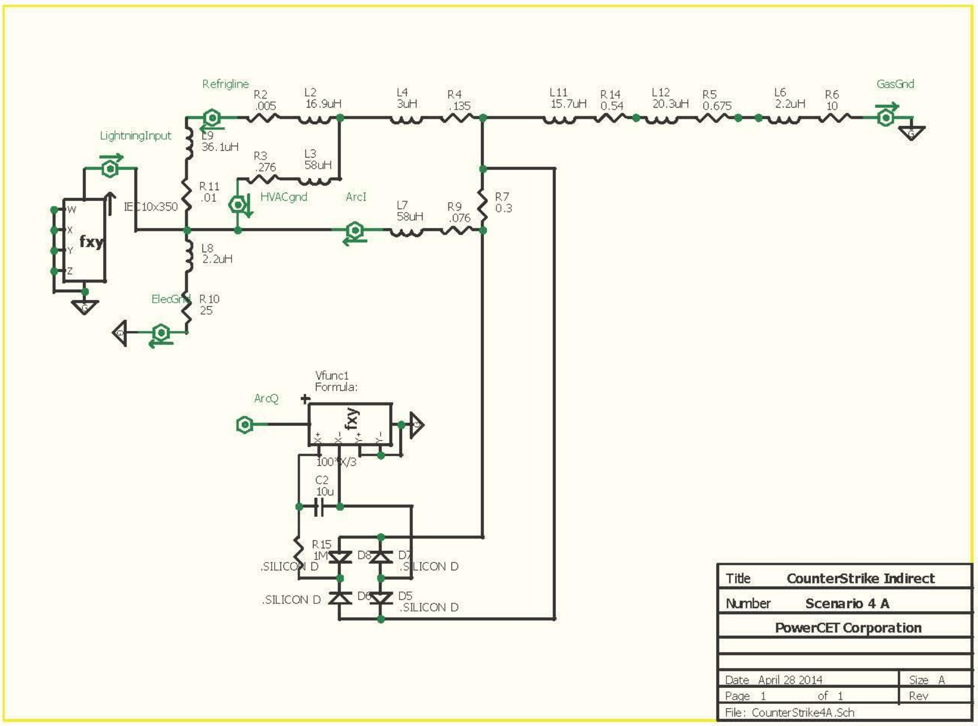


Fig. A 4: Scenario 4 simulation model

APPENDIX B

MEASURED & CALCULATED SELF-INDUCTANCE OF CSST

MEASURED & CALCULATED INDUCTANCE OF CSST LOOPS

The measurement of the self-inductance of linear conductors is non-trivial, since any laboratory measurement requires the injection of a current into the conductor as well as its return to the source through a second conductor. The self-inductance of the return conductor as well as mutual inductance between circuit elements makes this approach subject to variation resulting from the geometry of the test set-up.

PowerCET's approach is to measure the self-inductance of loops of conductor, which ensures that any test current injected flows only on the CSST and not on any other required return circuits. The measured value of inductance measured in this way is then compared with the calculated value of inductance using the standard formula given below.

$$L = \mu_0 n^2 R(\ln(8R/r)-2)$$

Where L is the self-inductance of the circular loop, R is the radius of the loop, n the number of turns and r the radius of the CSST. This formula ignores skin effects, considered a valid assumption for the frequencies involved.

Four samples were measured in this way, a 6.32 m length of ½" CSST formed into a two-turn circular loop of inside diameter 1.003m, a 4.445m length of ½" CSST formed into a two-turn loop of 0.346m inside diameter and a 4.445m length of 1" CSST formed into a two-turn loop of 0.338m inside diameter and a 9.3m length of ¾" CounterStrike. The self-inductance of each of these four samples was measured using an Agilent LCR meter. The calculated self-inductance was derived from the above formula, taking the effective radius of each CSST sample as half its maximum diameter (0.0095m for ½" CSST, 0.016m for 1" CSST and .019m for ¾" CounterStrike). The results of these measurements and calculations are shown in Table B1 below.

Sample	Measured Self-Inductance @ 10kHz	Calculated Self-Inductance
Two turns, 6.32m of ½" CSST	**9.61μH**	**10.15μH**
Two turns, 4.445m of ½" CSST	**6.35μH**	**6.39μH**
Two turns, 4.445m of 1" CSST	**5.38μH**	**5.32μH**
Two turns, 9.30 m of ¾" CounterStrike	**13.95μH**	**13.92μH**

Table B1: Measured and calculated self-inductance of CSST loops

CALCULATED INDUCTANCE OF LINEAR CSST

The self-inductance of linear conductors may be calculated using the formula attributed to Rosa:

$$L = (\mu_0/2\pi)l(\ln(2l/r)-1)$$

Where L is the self-inductance of the linear conductor, l is its length and r its radius. Like the earlier formula for circular loops, this also ignores skin effects.

CONCLUSIONS

The measured data for self-inductance of CSST show that it may be calculated to an accuracy of better than 90% using standard formulae. The Rosa formula for linear conductors may be applied, taking the effective radius of the CSST as one half of its largest diameter. The estimated self-inductance of linear ½" and 1" TracPipe and ¾" CounterStrike tubing for various lengths is given below in Table B2.

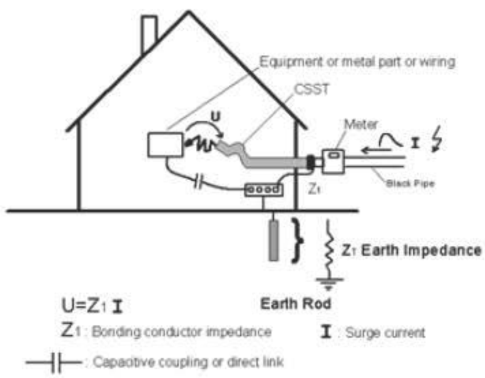
Length in meters	Self-Inductance ½" CSST	Self-Inductance 1" CSST	Self-Inductance ¾" CounterStrike
1	0.87μH	0.77μH	0.73μH
2	2.02μH	1.81μH	1.74μH
5	5.96μH	5.44μH	5.27μH
10	13.3μH	12.3μH	11.9μH
30	46.5μH	43.4μH	42.4μH

Table B2: Calculated self-inductance of TracPipe and CounterStrike

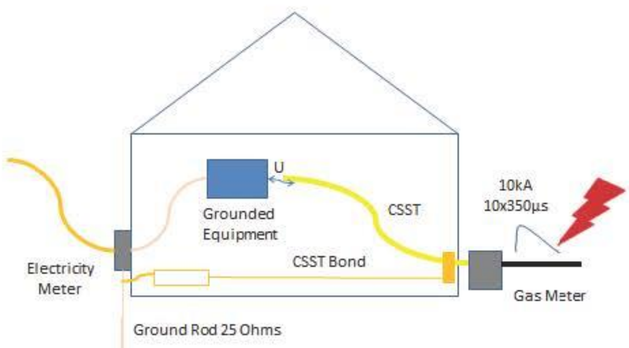
APPENDIX C

SIMULATION SCENARIOS DEVELOPED FOR ORIGINAL STUDY

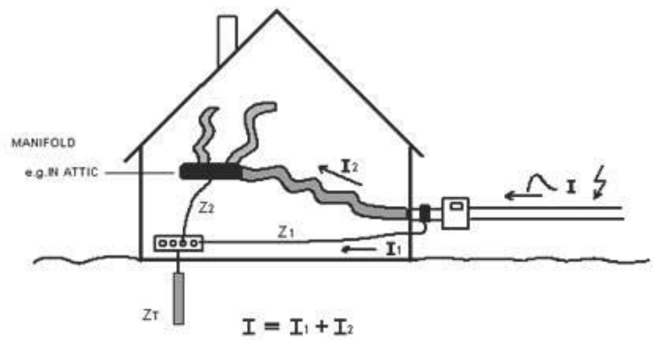
SEFTIM Proposed Scenario 1



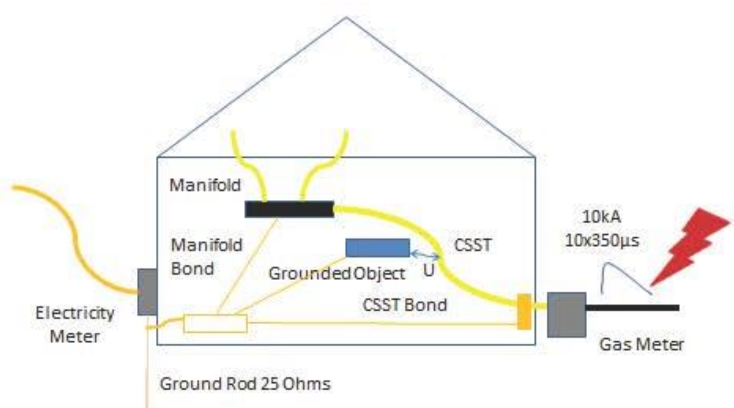
MFS Proposed Scenario 1



SEFTIM Proposed Scenario 2



MFS Proposed Scenario 2



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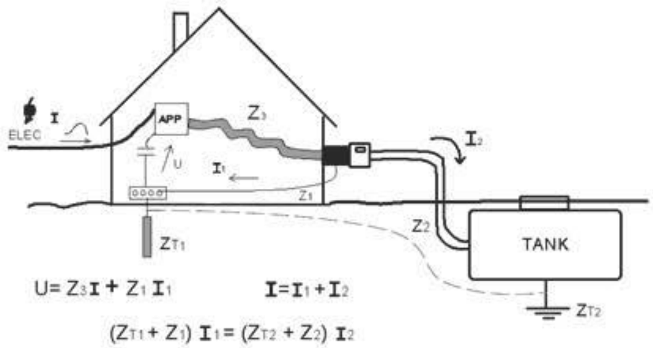
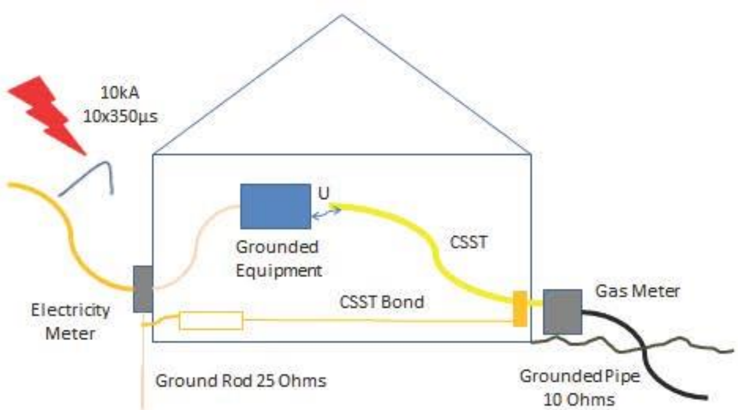
SEFTIM Proposed Scenario 3



MFS Proposed Scenario 3



APPENDIX D

LIGHTNING AND TEST WAVEFORMS

Lightning ground flashes may be considered to be a current source that consists of one or more impulsive currents together with longer continuing currents that may carry either negative or positive current from cloud to ground.

Negative downward lightning flashes, which comprise about 85% of ground flashes in the USA, have electrical parameters that are well-defined. Several experimental studies have recorded the magnitude and waveshape of first and subsequent strokes as well as continuing currents in these events. The median peak current for first negative strokes is 30 kA, 95% are larger than 14 kA and 5% are larger than 80 kA. The charge delivered by first strokes has a distribution of 95% larger than 1.1 C, a median of 5.2 C and 95% exceed 24 C. The charge delivered by subsequent strokes has a median of 1.4 C, 95% exceed 0.2 C and 5% exceed 11 C. The charge delivered by the whole negative flash has a median value of 7.5 C, 95% exceed 1.3 C and 5% exceed 40 C.

The risetime of the first stroke has a median of 5.5 µs and 5% are shorter than1.8 µs. The time to half value (tail time) has a median value of 75 µs and 5% are longer than 200 µs.

Positive downward flashes comprise about 15% of ground flashes in the USA and have electrical properties that are less well known. Most data on positive flashes that are used for lightning protection were derived from measurements of Berger on a mountain-top tower in Switzerland. It is widely acknowledged that Berger's data on positive flashes consisted mainly of upward discharges that are not representative of downward flashes. These upward flashes are believed to have longer durations and larger charge transfer than downward flashes. However, data from other sources does confirm that positive flashes have a greater incidence of large magnitude peak currents than negative flashes and also frequently contain continuing current that transfers more charge than negative flashes.

Berger's data gives a median positive flash current peak of 35 kA, 95% exceed 6 kA and 5% exceed 250 kA. The impulsive stroke charge has a median of 16 C, 95% exceed 90 C and 5% exceed 150 C. Total positive flash charge has a median of 80 C, 95% exceed 20 C and 5% exceed 350 C. These data give median risetimes for positive flashes of 22 µs, with 5% shorter than 3.5 µs. Stroke duration has a median value of 230 µs with 5% longer than 2 milliseconds.

Over the years, many laboratory test waveforms have been used to simulate lightning voltages and currents. The earliest impulsive voltage test waveforms used were double-exponential waves of approximately 1x50 µs and the earliest impulsive current waveform was 8x20 µs. The latter was selected because of limitations of early surge generators rather than being considered representative of lightning and it was discovered that discharging and 8x20 µs wave through a lightning arrester resulted in an approximately 1x50 µs voltage wave. Lightning currents in communications circuits were found to be longer duration, so a standard waveform of 10x1000 µs was developed for testing these. Continuing currents of lightning were simulated either by double-exponential waves of long duration or by rectangular waves (a switched dc source).

More recently, emphasis has been placed on the more energetic positive flashes and several waveforms have been developed for laboratory testing. The most common of these is the 10x350 µs wave, developed originally as a German DIN standard and adopted by the International Electrotechnical Commission (IEC) in its Lightning Protection Standards.

The tests in this report are based on both laboratory tests and computer simulations using the 10x350 μs and 10x1000 μs standard waveforms as well as two non-standard 10x2840 μs and 10x4000 μs waveforms. The latter resulted from limitations in the test generator.

STANDARD REFERENCES

1. ANSI/IEEE C 62.1-1984, Standard for Surge Arresters for AC Power Circuits.
2. ANSI C62.91-1982, Standard for Power Systems – Insulation Coordination
3. ANSI/IEEE C62.41-1991, Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits
4. Overvoltage Protection of Low Voltage Systems, Peter Hasse, IEE London, 2000
5. IEC 62305– 2013, Protection Against Lightning Part 1, General Principles

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PMG-1058

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Valid: 02/15 to 02/16

DIVISION: 23 00 00—HEATING, VENTILATING, AND AIR-CONDITIONING
SECTION: 23 11 00—FACILITY FUEL PIPING

REPORT HOLDER:

OMEGAFLEX® INC.

451 CREAMERY WAY
EXTON, PA 19341-2509

EVALUATION SUBJECT:

TRACPIPE® COUNTERSTRIKE® CONDUCTIVE JACKETED CORRUGATED STAINLESS STEEL TUBING

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PMG-1058

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CSI: DIVISION: 23 00 00—HEATING, VENTILATING, AND AIR-CONDITIONING
Section: 23 11 00—Facility Fuel Piping

Product certification system:

The ICC-ES product certification system includes testing samples taken from the market or supplier's stock, or a combination of both, to verify compliance with applicable codes and standards. The system also involves factory inspections, and assessment and surveillance of the supplier's quality system.

Product: TracPipe® CounterStrike® Conductive Jacketed Corrugated Stainless Steel Tubing

Listee: OmegaFlex® Inc.
451 Creamery Way
Exton, Pennsylvania 19341-2509
www.omegaflex.com

Compliance with the following codes:

2015, 2012, 2009 and 2006 *International Fuel Gas Code®* (IFGC)
2015, 2012, 2009 and 2006 *International Mechanical Code®* (IMC)
2015, 2012, 2009 and 2006 *International Residential Code®* (IRC)
2012, 2009 and 2006 *Uniform Plumbing Code®* (UPC)*
2012, 2009 and 2006 *Uniform Mechanical Code®* (UMC)*

Uniform Mechanical Code and Uniform Plumbing Code are copyrighted publications of the International Association of Plumbing and Mechanical Officials

Compliance with the following standards:

ANSI LC 1/CSA 6.26-2014, Fuel Gas Piping Systems Using Corrugated Stainless Steel Tubing (CSST)
NFPA 54-2015, National Fuel Gas Code
ICC-ES LC1024-2012, PMG Listing Criteria for Corrugated Stainless Steel Tubing Utilizing a Protective Jacket

Identification:

Tubing: Each 2 feet (610 mm) of tube bears the trade names TracPipe® CounterStrike®, part number, rated pressure [5 psi (34 kPa)], equivalent hydraulic diameter (EHD), the words "Fuel Gas", and the ICC-ES PMG listing mark.

Components**:** Fittings, termination outlets and distribution manifolds are stamped with the OmegaFlex® logo, the part number and a date stamp.

Installation:

General: Installation must be in accordance with the TracPipe® Flexible Gas Piping Guide and Installation Instructions, IFGC Section 404, IRC Section 2415, UMC Section 1309 and UPC Section 1211, as applicable. The system installation consists of CSST distribution lines installed between the point of delivery and fuel gas appliances. The use and system installation must be in accordance with ICC-ES PMG-1046.

Plenum Installation: When tested in accordance with ASTM E 84, TracPipe® CounterStrike® satisfies the plenum installation requirement, with a flame spread index of less than 25 and a smoke developed index of less than 50.

Electrical Bonding: The TracPipe® CounterStrike® Conductive Jacketed Corrugated Stainless SteelTubing (CSST) System is electrically continuous and is considered to be bonded where it is connected to appliances that are connected to the equipment grounding conductor of the circuit supplying that appliance. Additional bonding prescribed by IFGC Section 310.1.1 is not required for TracPipe® CounterStrike® Conductive Jacketed Corrugated Stainless Steel Tubing when it is installed in accordance with this listing.

Models: The TracPipe® CounterStrike® Conductive Jacketed CSST System consists of three parts: (1) a black conductive exterior jacket; (2) corrugated stainless steel tubing which is recognized in PMG-1046 as conforming to ANSI LC-1; and (3) mechanical fittings designed for use only with the OmegaFlex® Inc. CSSTs. Mechanical fittings utilize a metal-to-metal seal, and include mechanical fittings, distribution manifolds, shutoff valves, termination outlet devices, pressure regulators and protection devices.

Conditions of Listing:

1. TracPipe® CounterStrike® has been tested (in accordance with LC1024) and shown to resist a transient arc of 1000 amps minimum peak delivering 4.5 coulombs within 20 milliseconds (0.020 seconds). Assumed energy associated with a transient arc from lightning inside a building is less than 2.0 coulombs, providing a factor of safety of 2.25 for CounterStrike. Evaluation of this product for an arc exceeding this level or a direct strike from lightning is outside the scope of this listing.

2. The CSST piping system must not be used as a grounding electrode for an electrical system.

3. Additional information and requirements are defined in ICC-ES PMG-1046.

4. The TracPipe® CounterStrike® is manufactured by OmegaFlex® Inc. in Exton, Pennsylvania, under a quality control program with semi-annual surveillance inspections by ICC-ES.

TABLE 1—PART NUMBERS FOR TRACPIPE COUNTERSTRIKE TUBING

TUBING SIZE (inches)	PART NUMBER
3/8	FGP-CS-375-XXX
1/2	FGP-CS-500-XXX
3/4	FGP-CS-750-XXX
1	FGP-CS-100-XXX
1 1/4	FGP-CS-125-XXX
1 1/2	FGP-CS-150-XXX
2	FGP-CS-200-XXX

For **SI:** 1 inch = 25.4 mm.

XXX: Length of tubing in feet.

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CTP-603.3 cdpVA-15

Proponent : Carl Dale (carl.dale@scc.virginia.gov)

2015 International Plumbing Code

603.3 Tracer wire. Nonmetallic water service piping that connects to public systems shall be locatable. An insulated copper tracer wire, 18 AWG minimum in size and suitable for direct burial or an equivalent product shall be utilized. The wire shall be installed in the same trench as the water service piping and with-in 12 inches (305 mm) of the pipe and shall be installed to within five feet (1524 mm) of the building wall to the point where the building water service pipe intersects with the public water supply. At a minimum, one end of the wire shall terminate above grade to provide access to the wire in a location that is resistant to physical damage, such as with a meter vault or at the building wall.

Reason: In February 2014, a home exploded in Stafford County Virginia. The explosion was caused by damage to a nonmetallic water service utility line ("water lateral") that had not been installed with a tracer wire and had not been located prior to excavation. This excavation damaged the water lateral in the process of installing the natural gas utility service line. When the water was turned on for final occupancy permitting, the escaping water created an abrasive spray on the gas utility service line. The gas utility service line then ruptured due to the abrasive spray. Natural gas migrated into the home and found an ignition source which destroyed the home just days prior to occupancy.
The addition of a tracer wire requirement to non-metallic water piping in the Uniform Statewide Building Code ("USBC") will bring another layer of public safety inspection to construction sites across the Commonwealth. Local building inspectors would be empowered to inspect non-metallic water laterals for locatability as it pertains to the USBC at time of installation. These inspections would be similar to the inspection of non-metallic sewer utilities that are currently covered by the USBC.

Local building inspectors are regularly onsite at or near the time of installation of these water laterals during their construction. The building inspectors' ability to inspect/enforce this proposed requirement will minimize the chances of similar circumstances such as the Stafford explosion from occurring again by ensuring all non-metallic water laterals have tracer wires to facilitate excavators locating the water lateral for safe excavation around the water lateral.

This proposed change will also mirror the other requirements set forth in the Commonwealth under; § 56-257.1. "*Means of locating nonmetallic underground conduits*" and § 56-265.20:1. "*Locating nonmetallic underground utility lines*". It should also be noted that at least three municipalities, the Counties of Halifax[1], Loudoun[2], and the City of Charlottesville[3] in the Commonwealth, require non-metallic water laterals to have tracer wires on them.

[1] Halifax County Service Authority, "Minimum Requirements for Contractors performing work in relation to the Authority's Potable Water and Sanitary Sewer System", http://www.hcsa.us/files/HCSA-Tracer-Wire---General-Construction-Requirements.pdf (accessed December 16, 2014)

[2] Loudoun Water, "Letter to the Industry, February 10, 2011" Loudoun County http://www.loudounwater.org/uploadedFiles/Loudoun_Water/Developers_and_New_Construction/trace *(accessed December 16, 2014).*

[3]City of Charlottesville, *Potable Water and Sanitary Sewer Standard Specifications and Details*, (City of Charlottesville, January 2012) 24.

Cost Impact: The impact on both construction cost and time, along with the impact to the inspection process, would be minimal. Two large homebuilders in the Commonwealth have estimated total construction costs for installing tracer wire on water utility lines at .45 cents a foot for an estimated $25-30 per water service line installed. Currently during the new home construction process, sanitary sewer and water utilities are inspected at or near the same time for other USBC requirements. This inspection would only require a nominal amount of time for inspecting for the presence and type of a tracer wire on a water lateral that is already being inspected under other USBC requirements.

Workgroup Recommendation

Workgroup 3 Recommendation Recommendation: Consensus for Approval

Workgroup 3 Reason: 1st meeting: Gerber stated won't really help the issue-Emory stated talk to local water authority
2nd meeting: consensus for approval

Workgroup 4 Recommendation Recommendation: Pending

Workgroup 4 Reason: Presentation provided by Mr Dale-impact cost is minimal-3 localities require this-tweaks needed to the language-accessible terminology needs work.VPMIA will work with proponent.

Board Decision

None

<u>Board Decisions</u>

- ☐ Approved
- ☐ Approved with Modifications
- ☐ Carryover
- ☐ Disapproved
- ☐ None

CTP-603.3 cdpVA-15

CR-P2602.3 cdpVA-15

2602.3 (New)

Proponent : Carl Dale (carl.dale@scc.virginia.gov)

2015 International Residential Code

<u>**2602.3 Tracer Wire.** Nonmetallic water service piping that connects to public systems shall be locatable. An insulated copper tracer wire, 18 AWG minimum in size and suitable for direct burial or an equivalent product shall be utilized. The wire shall be installed in the same trench as the water service piping and within 12 inches (305 mm) of the pipe and shall be installed to within five feet (1524 mm) of the building wall to the point where the building water service pipe intersects with the public water supply. At a minimum, one end of the wire shall terminate above grade to provide access to the wire in a location that is resistant to physical damage, such as with a meter vault or at the building wall.</u>

Reason: In February 2014, a home exploded in Stafford County Virginia. The explosion was caused by damage to a nonmetallic water service utility line ("water lateral") that had not been installed with a tracer wire and had not been located prior to excavation. This excavation damaged the water lateral in the process of installing the natural gas utility service line. When the water was turned on for final occupancy permitting, the escaping water created an abrasive spray on the gas utility service line. The gas utility service line then ruptured due to the abrasive spray. Natural gas migrated into the home and found an ignition source which destroyed the home just days prior to occupancy.
The addition of a tracer wire requirement to non-metallic water piping in the Uniform Statewide Building Code ("USBC") will bring another layer of public safety inspection to construction sites across the Commonwealth. Local building inspectors would be empowered to inspect non-metallic water laterals for locatability as it pertains to the USBC at time of installation. These inspections would be similar to the inspection of non-metallic sewer utilities that are currently covered by the USBC.

Local building inspectors are regularly on-site at or near the time of installation of these water laterals during their construction. The building inspectors' ability to inspect/enforce this proposed requirement will minimize the chances of similar circumstances such as the Stafford explosion from occurring again by ensuring all non-metallic water laterals have tracer wires to facilitate excavators locating the water lateral for safe excavation around the water lateral.

This proposed change will also mirror the other requirements set forth in the Commonwealth under; § 56-257.1. "*Means of locating nonmetallic underground conduits*" and § 56-265.20:1. "*Locating nonmetallic underground utility lines*". It should also be noted that at least three municipalities, the Counties of Halifax[1], Loudoun[2], and the City of Charlottesville[3] in the Commonwealth, require non-metallic water laterals to have tracer wires on them.

[1] Halifax County Service Authority, "Minimum Requirements for Contractors performing work in relation to the Authority's Potable Water and Sanitary Sewer System", http://www.hcsa.us/files/HCSA-Tracer-Wire---General-Construction-Requirements.pdf (accessed December 16, 2014)

[2] Loudoun Water, "Letter to the Industry, February 10, 2011" Loudoun County http://www.loudounwater.org/uploadedFiles/Loudoun_Water/Developers_and_New_Construction/trace
(accessed December 16, 2014).

[3] City of Charlottesville, *Potable Water and Sanitary Sewer Standard Specifications and Details*, (City of Charlottesville, January 2012) 24.

Cost Impact: The impact on both construction cost and time, along with the impact to the inspection process, would be minimal. Two large homebuilders in the Commonwealth have estimated total construction costs for installing tracer wire on water utility lines at .45 cents a foot for an estimated $25-30 per water service line installed. Currently during the new home construction process, sanitary sewer and water utilities are inspected at or near the same time for other USBC requirements. This inspection would only require a nominal amount of time for inspecting for the presence and type of a tracer wire on a water lateral that is already being inspected under other USBC requirements.

Workgroup Recommendation

Workgroup 3 Recommendation Recommendation: Consensus for Approval

Workgroup 3 Reason: 1st meeting: Proponent not present-Vernon explained the proposal-Tracer wire on plastic water pipes.
No more discussion, No consensus

Workgroup 4 Recommendation Recommendation: Consensus for Approval

Workgroup 4 Reason: None

Board Decision

None

Board Decisions

- ☐ Approved
- ☐ Approved with Modifications
- ☐ Carryover
- ☐ Disapproved
- ☐ None

CR-P2602.3 cdpVA-15

CE-R402.1.1(2) cdpVA-15

Proponent : Eric Lacey (eric@reca-codes.com)

2012 Virginia Energy Conservation Code

TABLE R402.1.1
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b,e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.35	0.55	0.40	38	20~~15~~ or 13+5~~13+1~~[h]	8/13	19	10 /13	10, 2 ft	10 /13
5 and Marine 4	0.32	0.55	NR	49	20 or 13+5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.32	0.55	NR	49	20+5 or 13+10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.32	0.55	NR	49	20+5 or 13+10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

For SI: 1 foot = 304.8 mm.

R402.1.3 U-factor alternative.
An assembly with a *U*-factor equal to or less than that specified in Table R402.1.3 shall be permitted as an alternative to the *R*-value in Table R402.1.1.

TABLE R402.1.3
EQUIVALENT U-FACTORS[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR	SKYLIGHT *U*-FACTOR	CEILING *U*-FACTOR	FRAME WALL *U*-FACTOR	MASS WALL *U*-FACTOR[b]	FLOOR *U*-FACTOR	BASEMENT WALL *U*-FACTOR	CRAWL SPACE WALL *U*-FACTOR
1	0.50	0.75	0.035	0.082	0.197	0.064	0.360	0.477
2	0.40	0.65	0.030	0.082	0.165	0.064	0.360	0.477
3	0.35	0.55	0.030	0.057	0.098	0.047	0.091[c]	0.136
4 except Marine	0.35	0.55	0.030	0.060~~0.079~~	0.098	0.047	0.059	0.065
5 and Marine 4	0.32	0.55	0.026	0.057	0.082	0.033	0.050	0.055
6	0.32	0.55	0.026	0.048	0.060	0.033	0.050	0.055
7 and 8	0.32	0.55	0.026	0.048	0.057	0.028	0.050	0.055

a. Nonfenestration *U*-factors shall be obtained from measurement, calculation or an approved source.

2012 Virginia Residential Code

TABLE N1102.1.1
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR[b]	SKYLIGHT[b] *U*-FACTOR	GLAZED FENESTRATION SHGC[b,e]	CEILING *R*-VALUE	WOOD FRAME WALL *R*-VALUE	MASS WALL *R*-VALUE[i]	FLOOR *R*-VALUE	BASEMENT[c] WALL *R*-VALUE	SLAB[d] *R*-VALUE & DEPTH	CRAWL SPACE[c] WALL *R*-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13 + 5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.35	0.55	0.40	38	20~~15~~ or 13 + 5~~1~~[h]	8/13	19	10 /13	10, 2 ft	10/13
5 and Marine 4	0.32	0.55	NR	49	20 or 13 + 5[h]	13/17	30[g]	15/19	10, 2 ft	15/19
6	0.32	0.55	NR	49	20 + 5 or 13 + 10[h]	15/20	30[g]	15/19	10, 4 ft	15/19
7 and 8	0.32	0.55	NR	49	20 + 5 or 13 + 10[h]	19/21	38[g]	15/19	10, 4 ft	15/19

For SI: 1 foot = 304.8 mm.

TABLE N1102.1.3
EQUIVALENT U-FACTORS[a]

CLIMATE ZONE	FENESTRATION *U*-FACTOR	SKYLIGHT *U*-FACTOR	CEILING *U*-FACTOR	FRAME WALL *U*-FACTOR	MASS WALL *U*-FACTOR[b]	FLOOR *U*-FACTOR	BASEMENT WALL *U*-FACTOR	CRAWL SPACE WALL *U*-FACTOR
1	0.50	0.75	0.035	0.082	0.197	0.064	0.360	0.477
2	0.40	0.65	0.030	0.082	0.165	0.064	0.360	0.477
3	0.35	0.55	0.030	0.057	0.098	0.047	0.091[c]	0.136
4 except Marine	0.35	0.55	0.030	0.060~~0.079~~	0.098	0.047	0.059	0.065
5 and Marine 4	0.32	0.55	0.026	0.057	0.082	0.033	0.050	0.055
6	0.32	0.55	0.026	0.048	0.060	0.033	0.050	0.055
7 and 8	0.32	0.55	0.026	0.048	0.057	0.028	0.050	0.055

a. Nonfenestration *U*-factors shall be obtained from measurement, calculation or an approved source.

Reason: This proposal would make Virginia's energy code consistent with the 2015 IECC requirements for wall insulation. The U.S. DOE found both the 2012 and 2015 IECC to be cost-effective for Virginia (*see* https://www.energycodes.gov/development/residential/iecc_analysis/), and improvements to the thermal building envelope are important to the long-term efficiency and cost-effectiveness of new buildings.

The wall insulation R-values in the 2015 IECC do not require the use of any specific product, and can be achieved with either 2X4 or 2X6 wall construction. The two values in the prescriptive R-value table are only two of many different options. For additional wall insulation options, builders can use one of several compliance paths, each of which provides multiple options and combinations for meeting the code requirements:

- The U-factor alternative table (R402.1.4)
- The Total UA Alternative (R402.1.5)

- U.S. DOE's REScheck software (www.energycodes.gov)
- The Simulated Performance Alternative (R405)
- The Energy Rating Index (R406)

Wall insulation is easiest (and most cost-effective) to install during construction. Given that there may only be limited opportunities to upgrade the walls in the future, it is important to construct well-insulated walls from the very beginning. Better-insulated buildings are clearly an investment in Virginia's energy future. We recommend maintaining consistency with the 2015 IECC requirements.

This proposal also updates the equivalent U-factors to be consistent with the 2015 IRC/IECC, which is important for builders and design professionals who intend to use DOE's free REScheck compliance software. Virginia's reduced insulation requirements, among other weakening amendments in the 2012 Uniform Code, have made compliance via REScheck problematic. We recommend that Virginia adopt Equivalent U-factor values that will be consistent with the latest version of the IECC, both to maximize cost-effective energy efficiency and to maintain consistency with leading software compliance programs.

Cost Impact: This proposal may increase the cost of construction, depending on the compliance option selected.

Workgroup Recommendation

Workgroup 2 Recommendation Recommendation: Consensus for Disapproval

Workgroup 2 Reason: Andrew spoke on this for Eric-Gerber opposed-consensus for disapproval

Workgroup 3 Recommendation: None

Workgroup 3 Reason: None

Board Decision

None

Board Decisions

- ☐ Approved
- ☐ Approved with Modifications
- ☐ Carryover
- ☐ Disapproved
- ☐ None

CE-R402.1.1(2) cdpVA-15

From:	Maenner, Michael (DHCD)
To:	Andrew Grigsby; Davis, Cindy (DHCD)
Cc:	Chelsea Harnish
Subject:	RE: Wall insulation proposal
Date:	Thursday, September 22, 2016 2:24:46 PM

Good Afternoon Andrew

It was good to see you on Monday. I looked through our records and found the following information.

1. Our records indicate that Workgroup 2 had this as consensus for disapproval.
2. However the combined Workgroup had this as moved forward as non-consensus.

To remedy this error, we will bring this to the attention of the Board at the October meeting labeling CE-402.1.1(2) as non-consensus. We will request that it be carried over with the other two proposals of the same section and table to the final hearing.

Thank you for bringing this matter to my attention.

Best wishes,

Mike

Michael K. Maenner, Director
State Building Code Office
VA Dept. of Housing and Community Development
600 E. Main Street - Suite 1100
Richmond, VA 23219
PH: 804-371-7161
FAX: 804-371-7092

From: Andrew Grigsby [mailto:andrew@leap-va.org]
Sent: Thursday, September 22, 2016 12:25 PM
To: Davis, Cindy (DHCD); Maenner, Michael (DHCD)
Cc: Chelsea Harnish
Subject: Wall insulation proposal

Hi Cindy and Mike -

On Monday, this proposal: CE-R402.1.1(2) Insulation and fene ... Wall insulation value ... p. 287 - was listed in the "consensus for disapproval" table from the Workgroup. If it was Eric Lacey's proposal and I spoke for it and one person spoke against it (as the meeting notes indicate), why was it listed as consensus for disapproval? It now seems that the CSC got inaccurate information on this - and likely should reconsider.

your thoughts?
Andrew

Andrew Grigsby | Executive Director | Local Energy Alliance Program (LEAP)
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andrew@leap-va.org | www.leap-va.org