VIRGINIA DEPARTMENT OF HOUSING AND COMMUNITY DEVELOPMENT
DIVISION OF BUILDING AND FIRE REGULATION

Code Change Form for the 2012 Code Change Cycle

Code Change Number:________________

Proponent Information (Check one): X Individual Government Entity ☐Company

Name: Chuck Bajnai

Representing: self

Mailing Address: 9800 Government Center Parkway, Chesterfield, VA 23832

Email Address: bajnaic@chesterfield.gov

Telephone Number: 804-717-6428

Proposal Information

Code(s) and Section(s): R502.5 and R602.7.4

Proposed Change (including all relevant section numbers, if multiple sections):

Insert the following item into the list:

108.2 Exemption from application for permitting….

1. Installation of wiring….
2. Group R-5 decks that comply with all of the following:
    - 2.1 do not exceed 256 square feet in area,
    - 2.2 are not more than 24 inches above grade,
    - 2.3 are free standing, and
    - 2.4 do not serve the exit door required by Section R311.4
    - 2.5 are not in a flood plain.

~~2~~.3. One story detached accessory structures…

Renumber the others accordingly.

Submittal Information

Supporting Statement (including intent, need, and impact of the proposal):

A similar provision was put in the 2009 IRC (and carried forward in the 2012 IRC). It was automatically deleted by the deletion of chapter 1 by the VCC.

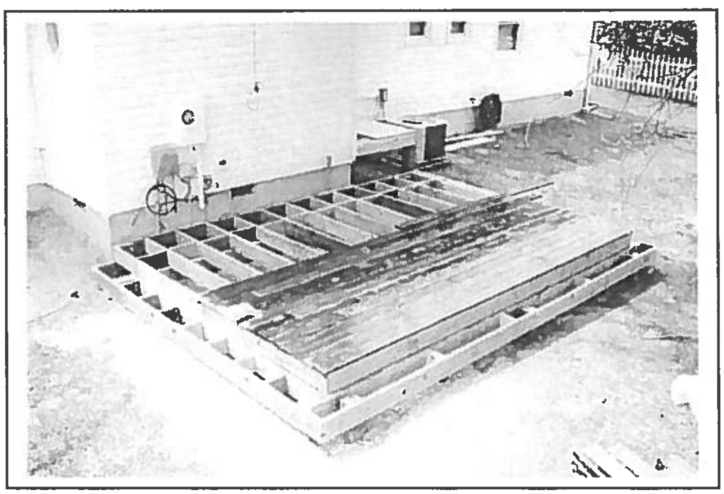
The VBCOA – IRC committee vetted this code change and most agreed that this code change had merit, but there were not enough participants for me to feel comfortable to submit it under the auspices of the VBCOA-IRC committee, hence I am submitting it on my own behalf.

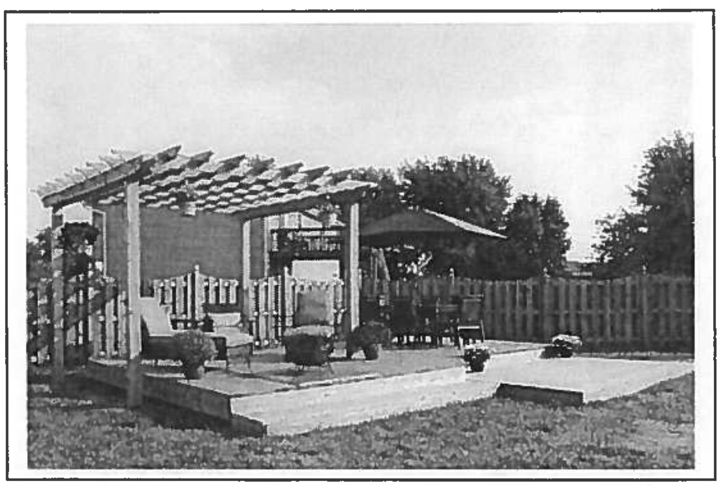
Several changes were made above and beyond the 2009 IRC:

1. format was changed to enumerate that ALL of these provisions have to apply
2. I changed the allowance up to 256 sqft to agree with the proposed change forthcoming regarding sheds and accessory structures.
3. I lowered the height down to 24" to basically say not more than 3 risers high…no guardrails or handrails would be required.
4. I added a flood plain requirement to be sure that these decks were not going to become floating platforms in case of a big flood.

This is a very good change and will make life easier for lots of folks, and many may even save a few dollars. It says that a permit is not required, but does not say that it is excluded from the requirements of the IRC – decks would still need to comply with the requirements for deck footings, joist sizes, etc.

Date Submitted: 9-18-2012





The proposal may be submitted by email as an attachment, by fax, by mail, or by hand delivery.

VIRGINIA DEPARTMENT OF HOUSING AND COMMUNITY DEVELOPMENT
DIVISION OF BUILDING AND FIRE REGULATION

Code Change Form for the 2012 Code Change Cycle

Code Change Number:______________________

Proponent Information (Check one): ☐ Individual X Government Entity ☐ Company

Name: John S. Trenary, CBO

Representing: Region III VBCOA / Frederick County

Mailing Address: Frederick County Inspections Department, 107 N. Kent Street, Winchester VA 22601

Email Address: jtrenary@co.frederick.va.us

Telephone Number: (540)665-5650

Proposal Information

Code(s) and Section(s): IRC 2012 Section R507.2.3 Deck lateral load connection

Proposed Change (including all relevant section numbers, if multiple sections):

R507.2.3 Deck lateral load connection. The lateral load connection required by Section R507.1 shall be permitted to be in accordance with Figure R507.2.3. Where the lateral load connection is provided in accordance with Figure 507.2.3, hold-down tension devices shall be installed in not less than two locations per deck, ____ each device shall **be spaced so one is located in each end of the deck attachment at a minimum distance apart of one third of the horizontal length** and have an allowable stress design capacity of not less than 1500 pounds (6672N).

Supporting Statement (including intent, need, and impact of the proposal):
This code change would clarify the intent of the code for the proper spacing of the tension devices when they are utilized. The current language would not prevent the installation of the two devices at a single location.

Cost Impact: This code change should not increase the cost of construction.

Submittal Information

Date Submitted: June 13, 2012

The proposal may be submitted by email as an attachment, by fax, by mail, or by hand delivery.

Please submit the proposal to:

DHCD DBFR TASO (Technical Assistance and Services Office)
600 East Main Street
Suite 300
Richmond, VA 23219

Email Address: taso@dhcd.virginia.gov
Fax Number: (804) 371-7092
Phone Numbers: (804) 371-7140 or (804) 371-7150

VIRGINIA DEPARTMENT OF HOUSING AND COMMUNITY DEVELOPMENT
DIVISION OF BUILDING AND FIRE REGULATION

Code Change Form for the 2012 Code Change Cycle

Code Change Number:______________________________

Proponent Information (Check one): ☐ Individual X Government Entity ☐ Company

Name: Chuck Bajnai, Chesterfield County
Bryan Deem, Stafford County

Representing: VBCOA –IRC committee

Mailing Address: 9800 Government Center Parkway, Chesterfield, VA 23832

Email Address: bajnaic@chesterfield.gov

Telephone Number: 804-717-6428

Proposal Information

Code(s) and Section(s): R502.5 and R602.7.4

Proposed Change (including all relevant section numbers, if multiple sections):

1. Add new section as follows:

R502.5 Allowable girder spans. The allowable spans of girders fabricated of dimension lumber shall not exceed the values set forth in Tables R502.5(1) and R502.5(2). Girders shall be supported laterally at the ends to prevent rotation.

2. Modify Table R502.5(1), footnote d as follows:

TABLE R502.5(1)—continued
GIRDER SPANS[a] AND HEADER SPANS[a] FOR EXTERIOR BEARING WALLS
(Maximum spans for Douglas fir-larch, hem-fir, southern pine and spruce-pine-fir[b] and required number of jack studs)

GIRDERS AND HEADERS SUPPORTING	SIZE	GROUND SNOW LOAD (psf)[e]																	
		30						50						70					
		Building width[c] (feet)																	
		20		28		36		20		28		36		20		28		36	
		Span	NJ[d]	Span	NJ[d]	Span	NJ[d]	Span	NJ[d]	Span	NJ[d]	Span	NJ[d]	Span	NJ[d]	Span	NJ[d]	Span	NJ[d]
Roof, ceiling, and two clear span floors	2-2 × 10	4-9	2	4-1	3	3-8	3	4-8	2	4-0	3	3-7	3	4-7	3	4-0	3	3-6	3
	2-2 × 12	5-6	3	4-9	3	4-3	3	5-5	3	4-8	3	4-2	3	5-4	3	4-7	3	4-1	4
	3-2 × 8	4-10	2	4-2	2	3-9	2	4-9	2	4-1	2	3-8	2	4-8	2	4-1	2	3-8	2
	3-2 × 10	5-11	2	5-1	2	4-7	3	5-10	2	5-0	2	4-6	3	5-9	2	4-11	2	4-5	3
	3-2 × 12	6-10	2	5-11	3	5-4	3	6-9	2	5-10	3	5-3	3	6-8	2	5-9	3	5-2	3
	4-2 × 8	5-7	2	4-10	2	4-4	2	5-6	2	4-9	2	4-3	2	5-5	2	4-8	2	4-2	2
	4-2 × 10	6-10	2	5-11	2	5-3	2	6-9	2	5-10	2	5-2	2	6-7	2	5-9	2	5-1	2
	4-2 × 12	7-11	2	6-10	2	6-2	3	7-9	2	6-9	2	6-0	3	7-8	2	6-8	2	5-11	3

For SI: 1 inch = 25.4 mm, 1 pound per square foot = 0.0479 kPa.

a. Spans are given in feet and inches.
b. Tabulated values assume #2 grade lumber.
c. Building width is measured perpendicular to the ridge. For widths between those shown, spans are permitted to be interpolated.
d. NJ – Number of jack studs required to support each end. A king stud shall be required adjacent to the jack stud on each side, and nailed to the header with (4) 16d nails on each side. Where the number of required jack studs equals one, the header is permitted to be supported by an approved framing anchor attached ~~to the full-height wall stud and to~~ between the king stud and the header.
e. Use 30 psf ground snow load for cases in which ground snow load is less than 30 psf and the roof live load is equal to or less than 20 psf.

3. Modify Table R502.5(2), footnote d as follows

TABLE R502.5(2)
GIRDER SPANS[a] AND HEADER SPANS[a] FOR INTERIOR BEARING WALLS
(Maximum spans for Douglas fir-larch, hem-fir, southern pine and spruce-pine-fir[b] and required number of jack studs)

HEADERS AND GIRDERS SUPPORTING	SIZE	BUILDING Width[c] (feet)					
		20		28		36	
		Span	NJ[d]	Span	NJ[d]	Span	NJ[d]
One floor only	2-2 × 4	3-1	1	2-8	1	2-5	1
	2-2 × 6	4-6	1	3-11	1	3-6	1
	2-2 × 8	5-9	1	5-0	2	4-5	2
	2-2 × 10	7-0	2	6-1	2	5-5	2
	2-2 × 12	8-1	2	7-0	2	6-3	2
	3-2 × 8	7-2	1	6-3	1	5-7	2
	3-2 × 10	8-9	1	7-7	2	6-0	2
	3-2 × 12	10-2	2	8-10	2	7-10	2
	4-2 × 8	9-0	1	7-8	1	6-9	1
	4-2 × 10	10-1	1	8-9	1	7-10	2
	4-2 × 12	11-9	1	10-2	2	9-1	2
Two floors	2-2 × 4	2-2	1	1-10	1	1-7	1
	2-2 × 6	3-2	2	2-9	2	2-5	2
	2-2 × 8	4-1	2	3-6	2	3-2	2
	2-2 × 10	4-11	2	4-3	2	3-10	3
	2-2 × 12	5-9	2	5-0	3	4-5	3
	3-2 × 8	5-1	2	4-5	2	3-11	2
	3-2 × 10	6-2	2	5-4	2	4-10	2
	3-2 × 12	7-2	2	6-3	2	5-7	3
	4-2 × 8	6-1	1	5-3	2	4-8	2
	4-2 × 10	7-2	2	6-2	2	5-6	2
	4-2 × 12	8-4	2	7-2	2	6-5	2

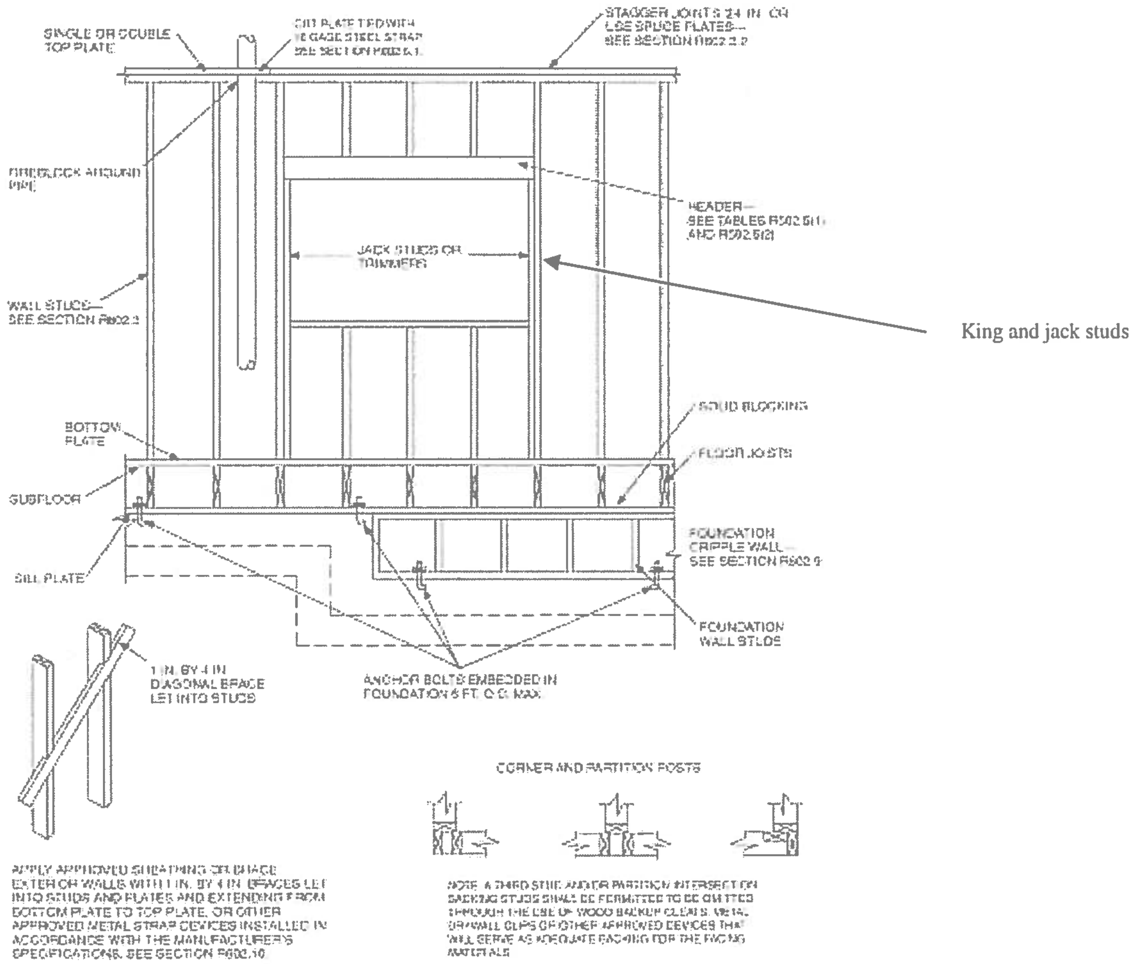
For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

a. Spans are given in feet and inches.
b. Tabulated values assume #2 grade lumber.
c. Building width is measured perpendicular to the ridge. For widths between those shown, spans are permitted to be interpolated.
d. NJ – Number of jack studs required to support each end. A king stud shall be required adjacent to the jack stud on each side, and nailed to the header with (4) 16d nails on each side. Where the number of required jack studs equals one, the header is permitted to be supported by an approved framing anchor attached ~~to the full-height wall stud and to~~ between the king stud and the header.

4. Add new section as follows:

R602.7.4 Supports for headers. Headers shall be supported on each end with a jack stud in accordance with Table R502.5 (1) or Table R502.5(2). A king stud as shown in Figure R602.3(2) shall be adjacent to the jack stud(s) on each side and nailed to each end of the header with (4) 16d nails .

5. Modify Figure R602.3(2) as follows:



For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm.

FIGURE R602.3(2)
FRAMING DETAILS

Supporting Statement (including intent, need, and impact of the proposal):

Reason:
The code is tacit about how headers should be supported. To prevent top chord buckling, the king stud should be used to stabilize the header by nails on each end. This code section puts the requirement into the code.

Submittal Information

Date Submitted: 9-5-2012

The proposal may be submitted by email as an attachment, by fax, by mail, or by hand delivery.

Please submit the proposal to:

DHCD DBFR SBCO (State Building Codes Office)
600 East Main Street
Suite 300
Richmond, VA 23219

Email Address: Vernon.hodge@dhcd.virginia.gov
Fax Number: (804) 371-7092
Phone Numbers: (804) 371-7150

VIRGINIA DHCD

VIRGINIA DEPARTMENT OF HOUSING AND COMMUNITY DEVELOPMENT
DIVISION OF BUILDING AND FIRE REGULATION

Code Change Form for the 2012 Code Change Cycle

Code Change Number:____________________

Proponent Information (Check one): ☐ Individual ☐ Government Entity X Company

Name: Robert Torbin Representing: Omega Flex, Inc

Mailing Address: 213 Court Street Suite 1001 Middletown, CT 06457

Email Address: bob.torbin@omegaflex.net Telephone Number: (413) 388-2390

Proposal Information

Code(s) and Section(s): USBC G2411.1

Proposed Change (including all relevant section numbers, if multiple sections):

ADD THE FOLLOWING NEW TEXT TO SECTION G2411.1:

CSST with an arc-resistant jacket listed by an approved agency for installation without the direct bonding, as prescribed in this section, shall be installed in accordance with its listing and the manufacturer's installation instructions.

Supporting Statement (including intent, need, and impact of the proposal):

See attached Supporting Statement.

Submittal Information

Date Submitted: 6 August 2012

The proposal may be submitted by email as an attachment, by fax, by mail, or by hand delivery.

Please submit the proposal to:

DHCD DBFR SBCO (State Building Codes Office)
600 East Main Street
Suite 300
Richmond, VA 23219

Email Address: Vernon.hodge@dhcd.virginia.gov
Fax Number: (804) 371-7092
Phone Numbers: (804) 371-7150

VIRGINIA DHCD

Supporting Statement

The use of a CSST product with a protective, arc-resistant jacket is an alternate method of protection against electrical arcing damage caused by high voltage transient events such as a nearby lightning strike. An arc-resistant jacket does not rely on direct bonding to the grounding electrode system to reduce or eliminate damage from electrical arcing. Instead, the protective jacket acts as a resistor and is designed to locally absorb and dissipate the arcing energy over a short length of the jacket. 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 regardless of the bonding conductor size or length. 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 ICC Evaluation Service has developed listing criteria for arc-resistant jackets to verify that this design approach will provide an ability to resist damage from transient arcing currents under a wide range of conditions. A copy of the PMG Listing Criteria (LC1024) is included with this proposal. Currently, three CSST products are listed to PMG LC1024. The listing criteria defines the experimental means to determine whether the protective jacket provides resistance to damage from indirect lightning strikes without the need for additional bonding as prescribed currently in Section G2411.1 of the VA Uniform Statewide Building Code. A proposal to include performance requirements for an arc-resistant jacket based on the PMG LC1024 Listing Criteria is presently under consideration by the ANSI LC-1 TAG.

Extensive testing has been performed by Lightning Technologies Inc. (Pittsfield, MA) to demonstrate that the protective, arc-resistant jacket can resist in excess of 4.5 coulombs without a perforation of the tubing wall. A copy of a pertinent LTI test report is attached. By comparison, experimental testing has determined that energy levels around 0.15 coulombs are sufficient to perforate uncoated CSST. While no product or system is immune to damage from a direct lightning strike, lightning experts agree that a level of approximately 2 coulombs is the upper end of the energy level induced in metallic systems (inside the building) from a nearby/indirect lightning strike. A recent IEEE paper by Dr. Michael Stringfellow (attached) on lightning damage confirms that the proposed energy value (2 coulombs and lower) appears consistent with lightning damage observed in the field, and the acceptance level (4.5 coulombs) represents an appropriate safety threshold for this type of lightning protection.

The cost impact to the consumer of allowing the use of arc-resistant jacket CSST as an alternate method of bonding CSST should be minimal if not zero. The small extra cost per foot of arc-resistant jacket is more than offset by the elimination of the two bonding connections, the 6 AWG conductor wire, and the labor time for the electrician to install.

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 no known cases of indirect lightning damage to CSST piping systems using these arc-resistant jackets. Currently, at least 10 states permit the installation of the arc-resistant CSST without the need for additional bonding. Given that both conventional (yellow) and advanced (black) CSST products will continue to be commercially available, both methods of electrical protection of CSST systems should be recognized and permitted within the Code.

ICC-ES PMG Listing

PMG-1058

Effective Date: February 1, 2012
This listing is subject to re-examination in one year.

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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:

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

**Uniform Mechanical Code* and *Uniform Plumbing Code* are copyrighted publications of the International Association of Plumbing and Mechanical Officials, 5001 East Philadelphia Street, Ontario, California 91761.

Compliance with the following standards:

ANSI LC 1/CSA 6.26, Fuel Gas Piping Systems Using Corrugated Stainless Steel Tubing (CSST)
NFPA 54, National Fuel Gas Code
LC1024, PMG Listing Criteria for Conductive Jacketed Corrugated Stainless Steel Tubing

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", the name of the third-party inspection agency [CSA International (AA-659)] 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 IAPMO 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 CSA International (AA-659).

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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PROPOSED PMG LISTING CRITERIA FOR

CORRUGATED STAINLESS STEEL TUBING UTILIZING A PROTECTIVE JACKET

LC1024

Approved February 2010
(Revised February 2012)

PREFACE

Plumbing, mechanical and fuel gas (PMG) listings issued by ICC Evaluation Service, LLC (ICC-ES), are based upon performance features of the *International Plumbing Code®*, *International Mechanical Code®*, *International Residential Code®*, *Uniform Plumbing Code and Uniform Mechanical Code*. Section 105.2 of the *International Plumbing Code®* reads as follows:

> **Materials, methods and equipment.** The provisions of this code are not intended to prevent the installation of any material or to prohibit any method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material or method of construction shall be approved where the code official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.

Similar provisions are contained in the Uniform Codes.

ICC-ES may consider alternate listing criteria, provided the listing applicant submits valid data demonstrating that the alternate listing criteria are at least equivalent to the listing criteria set forth in this document, and otherwise demonstrate compliance with the performance features of the codes. Notwithstanding that a product, material, or type or method of construction meets the requirements of the criteria set forth in this document, or that it can be demonstrated that valid alternate criteria are equivalent to the criteria in this document and otherwise demonstrate compliance with the performance features of the codes, ICC-ES retains the right to refuse to issue or renew a listing, if the product, material, or type or method of construction is such that either unusual care with its installation or use must be exercised for satisfactory performance, or if malfunctioning is apt to cause unreasonable property damage or personal injury or sickness relative to the benefits to be achieved by the use of the product, material, or type or method of construction.

Listing criteria are developed solely for use by ICC-ES for purposes of issuing ICC-ES PMG listings.

1.0 INTRODUCTION

1.1 Purpose: The purpose of this listing criteria is to establish the effectiveness of a protective exterior jacket factory-applied to corrugated stainless steel tubing (CSST) which is currently recognized as code-complying in another ICC-ES PMG listing report. The exterior jacket is intended to protect the inner CSST from leakage due to transient arcing from exposure to lightning voltage/currents that may exist inside a building; utilize the appliance bond as the sole bonding method; and be recognized in an ICC Evaluation Service, Inc. (ICC-ES) listing. This listing criteria addresses a proposed level of arcing from lightning, not a direct strike.

1.2 Scope: This listing criteria defines test methods and performance requirements applicable for evaluating simulated indirect lightning resistance of a protective exterior jacket factory-applied over CSST which is currently recognized in an ICC-ES PMG listing. The lightning-resistant CSST system, for use in fuel gas piping, is intended for use in normal installations when installed in compliance with the manufacturer's instructions and with Sections 309 and 310 of the *International Fuel Gas Code*© and Sections G2410 and G2411 of the *International Residential Code*©.

1.3 Codes and Referenced Standards:

Note: Any standard referenced herein shall be the current edition of that standard.

1.3.1 2006 and/or 2009 *International Residential Code*© (IRC), Chapter 24, Fuel Gas, International Code Council.

1.3.2 2006 and/or 2009 *International Fuel Gas Code*© (IFGC), International Code Council.

1.3.3 2006 and/or 2009 *Uniform Plumbing Code*™* (IAPMO UPC), Chapter 12, Fuel Gas Piping, International Association of Plumbing and Mechanical Officials.

1.3.4 2006 and/or 2009 *Uniform Mechanical Code*™* (IAPMO UMC), Chapter 13, Fuel Gas Piping, International Association of Plumbing and Mechanical Officials.

1.3.5 ANSI LC 1 / CSA 6.26, Fuel Gas Piping Systems Using Corrugated Stainless Steel Tubing (CSST) Fuel Gas. American National Standards Institute.

2.0 BASIC INFORMATION

The following basic information shall be provided:

2.1 Product Description: The product consists of corrugated stainless steel tubing (CSST) and brass fittings for fuel gas piping systems recognized in another current ICC-ES PMG listing as conforming to ANSI LC 1 / CSA 6.26, and satisfying the referenced codes listed in Section 1.3, but, with a different covering. The CSST is covered with an electrically conductive protective jacket.

2.2 Installation Instructions: The product shall be installed in accordance with the manufacturer's instructions and the requirements of the applicable codes and referenced standards listed in Section 1.3.

2.3 Product and Packaging Identifications: The unit and the package shall be permanently and legibly marked with the manufacturer's name or trademark, and the model number. The product shall also bear the ICC-ES PMG listing mark. The ICC-ES listing number shall be placed on the listed product's packaging or installation instructions.

3.0 GENERAL REQUIREMENTS

3.1 Corrugated Stainless Steel Tubing: Corrugated stainless tubing shall be currently recognized in an ICC-ES PMG listing as complying with the requirements of ANSI LC 1 / CSA 6.26.

3.2 Electrically Conductive Protective Jacket: The product shall be tested in accordance with Section 4.0 of this standard.

4.0 TEST METHOD AND PERFORMANCE REQUIREMENTS

4.1 Testing: Testing shall be performed by an International Accreditation Service (IAS) recognized lightning testing laboratory or by a signatory to a Mutual Recognition Agreement to which IAS is a signatory.

4.2 Specimen Conditioning: The specimen used for testing shall be previously subjected to a 96-hr corrosion test conducted in accordance with ASTM B117 without evidence of pitting, flaking, cracking or signs of corrosive attack. The specimen must include the protective jacket on a section of CSST and be joined to a fitting in accordance with the manufacturer's installation instructions.

Note: Additional conditioning is only applicable to specimens that contain any metallic components that were not previously evaluated in accordance with ASTM B117 under ANSI LC1. These specimens shall also be tested with fittings installed in accordance with manufacturer's instructions.

4.3 Test Wave Forms: The waveform is defined by its rise-time to peak current and fall-time to 50% of peak amplitude. The applied current wave form shall be determined by the lightning laboratory and shall be representative of induced lightning effects that could appear on gas piping inside a building. For the purposes of this listing criteria, the assumed energy associated with a transient arc inside a building is less than two coulombs and the recognized CSST system must resist a minimum of 4.5 coulombs, which includes a factor of safety in excess of 2, when tested as noted in this listing criteria. A typical current wave form is shown in Figure 1.

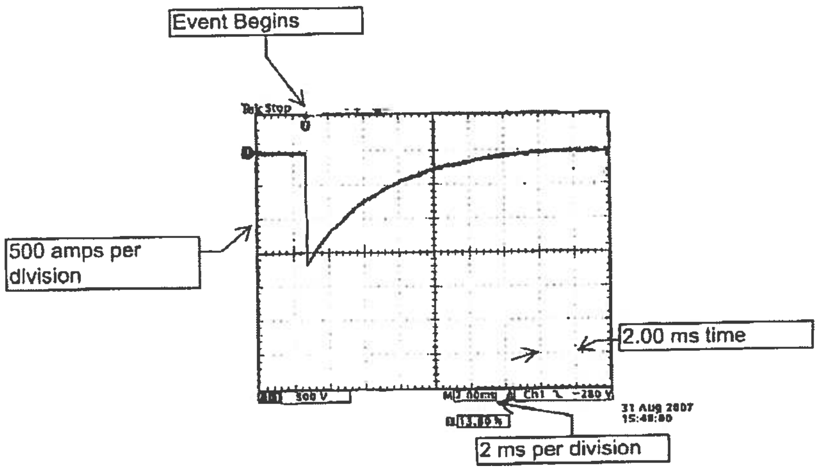

FIGURE 1—TYPICAL CURRENT WAVE FORM

4.4Test Procedures: The procedures noted below shall be used to evaluate the performance of CSST piping. Testing shall be conducted on two samples each of the smallest, largest and an intermediate diameter tubing to qualify all sizes. The minimum performance criteria shall be 1,000 amps minimum peak delivering 4.5 coulombs within 20 milliseconds (0.020 seconds). Following exposure to this level of arcing, the sample shall be pressure-tested to 5 PSI for 1 minute with air and submerged in water without signs of leakage.

4.4.1Calibration: A test generator is configured to produce and measure the desired current waveform. An appropriately sized copper pipe is installed $^{1}/_{8}$ inch underneath the generator's test electrode and grounded to the generator return with a minimum AWG 6 wire or braided strap. The generator is charged to the appropriate level. The generator is then discharged through the copper pipe, and the applied current waveform is recorded. The generator is verified as producing the desired current waveform. The measured current waveform is integrated to determine the applied charge to the copper pipe. The current waveform and charge transfer waveform are recorded. If the high current generator does not yield the desired current waveform or charge transfer, the generator is reconfigured, and the calibration procedures are repeated. The copper pipe is removed from the generator.

4.4.2 Testing:

4.4.2.1 Arcing Resistance: A minimum 3-foot-long CSST test article is installed at least $^{1}/_{8}$ inch beneath a $^{1}/_{4}$-inch-diameter test electrode. The electrode shall be placed at least 12 inches from the ends of the test article. The brass fitting or inner stainless steel piping of the CSST is grounded to the generator return using a minimum AWG 6 wire or braided strap. A dielectric may be required underneath the test article to ensure the test currents flow along the length of the test article and not to the test bench or support equipment. The lightning generator is charged to the appropriate level, and is then discharged to the test article. If the test generator does not discharge to the test article, it shall be confirmed that sufficient voltage is present to achieve dielectric breakdown of the jacket (energy enter the jacket and not to ground) and adjustments are made accordingly. It is verified that the test current enters the protective jacket and did not arc to any exposed tubing or fittings on either end of the test article. If all or a portion of the test current arced to the exposed ends or fittings of the test article, the test is invalid and must be repeated. The applied current waveform is recorded. The measured current waveform is integrated to calculate the applied charge. If the calculated applied charge is equal to or greater than the values stated in Section 4.4, the applied charge transfer is recorded. The jacket is cut away from the test article at the test location and a visual inspection of the tubing is made to determine if the stainless steel tubing is punctured. If no puncture of the tubing is noted on visual inspection, the test article shall be pressure-tested to the requirements of Section 4.4. If the test article fails visual inspection or pressure test after being subjected to the required applied charge, the test article fails. If the calculated applied charge is less than the values stated in Section 4.4, the test is performed again at a different location on the same test article, or another test article from the same production lot, until the calculated applied charge requirements are satisfied. The test article is deemed to have passed if all of the requirements are met. In order to achieve a listing to this standard, no test articles can fail this test routine. See Figure 2 for test schematic.

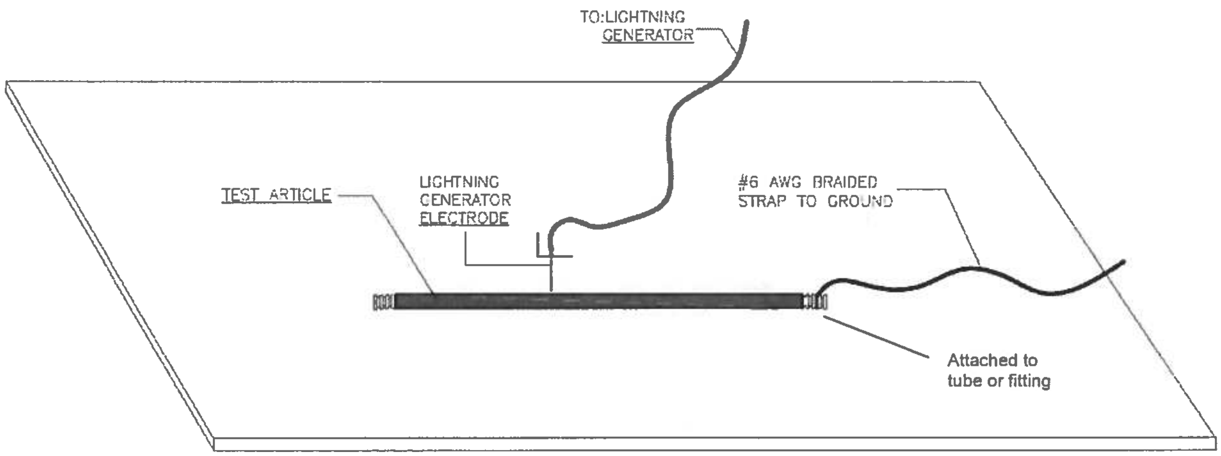

FIGURE 2—TEST SCHEMATIC

4.4.2.2 Bonding Equivalence: For the purpose of evaluating the conductive jacket for resistance to transient arcing using different bonding methods, testing in accordance with this section shall be performed using a simulated appliance consisting of:

1. A steel sheet metal chassis
2. An NPT connection point for the CSST
3. An electrical box with a minimum 10-foot-long, #14 AWG bonding conductor attached
4. A bonding clamp attached to the fitting on the free end of the CSST and a minimum 10-foot-long, #6 AWG bonding conductor

A minimum of two samples of an intermediate size of CSST shall be tested using the following configurations:

1. The #14 AWG conductor as the bond
2. The #6 AWG conductor as the bond
3. Using both as the bond

If the test results for all three configurations comply with Section 4.4.2, bonding of the conductive jacketed corrugated tubing, using a #14 AWG appliance bond, shall be deemed equivalent to using a #6 AWG bond required by IFGC 310.1.1. See Figure 3 for a test schematic.

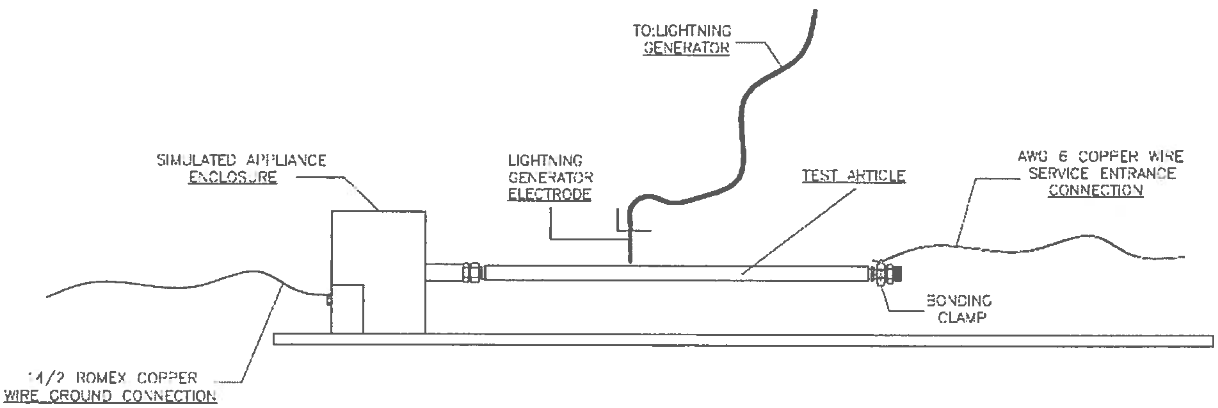

FIGURE 3—TEST SCHEMATIC

4 LISTING RECOGNITION

4.2 Installation shall be in accordance with the manufacturer's instructions and the applicable code.

4.3 The listing shall state that the documented level of resistance to arcing is 1000 amps minimum peak delivering 4.5 coulombs within 20 milliseconds (0.020 seconds).

4.4 The listing shall state the covering has been tested in accordance with ASTM E 84 and meets the minimum ratings of 25 for flame spread and 50 for smoke developed.

4.5 Upon documentation of satisfactory passing of tests noted in Section 4.4.2.2 of this criteria, the listing shall state the following: "Electrical Bonding: The Conductive Jacketed Corrugated Stainless Steel Tubing 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 Section 310.1.1 is not required for Conductive Jacketed Corrugated Stainless Steel Piping Systems when installed in accordance with this listing."

LT-10-3241

TEST REPORT:

COMPARISON OF GROUNDING TECHNIQUES

FOR OMEGAFLEX COUNTERSTRIKE GAS PIPING

Prepared by:

A. L. Hall

Approved by:

M. M. Dargi

For

OmegaFlex, Inc.
451 Creamery Way
Exton, PA 19341-2509

Purchase Order No. 145685

Tests by:

A. L. Hall
D. Deblois
P. Saldo

Witnessed by:

S. Treichel
(*OmegaFlex*)

Test dates:

29-30 December 2009

References:

LTI-4187
DB 336, pp. 38-39

15 January 2010

Lightning Technologies, Inc.
10 Downing Industrial Parkway
Pittsfield, MA 01201-3890
U.S.A.

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1.0 INTRODUCTION

Simulated lightning currents were applied to OmegaFlex's ¾" CounterStrike gas piping to evaluate its ability to withstand melt-through of the inner stainless steel pipe using three different bonding/grounding methods. Test results relate only to the items/part numbers tested.

A. Hall, P. Saldo, and D. DeBlois performed the tests at Lightning Technologies Inc. (LTI) in Pittsfield, MA during the period of 29-30 December 2009. S. Treichel of OmegaFlex, Inc. witnessed the testing.

2.0 SUMMARY

Testing was performed to evaluate the ability of CounterStrike gas piping to resist simulated lightning currents using a 14 AWG ground wire versus a 6 AWG ground wire as described in the 2009 International Fuel Gas Code sections 310.1 and 310.1.1. These sections read as follows.

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.

310.1.1 CSST. Corrugated stainless steel tubing (CSST) gas piping systems shall be bonded to the electrical service grounding electrode system at the point where the gas service enters the building. The bonding jumper shall not be smaller than 6 AWG copper wire or equivalent.

One end of 48" long samples of ¾" CounterStrike were attached to a sheet metal chassis with a standard OmegaFlex fitting and an appliance termination to simulate the connection to a household appliance, such as a gas dryer. An electrical box and 14 AWG copper Romex cable were attached to the metal chassis to simulate an electrical connection to the appliance. The other end of the CounterStrike samples had a bonding clamp attached to the fitting for connecting a 6 AWG copper wire.

Three bonding configurations of the CounterStrike were evaluated in a laboratory set-up which represented a typical appliance installation. The three configurations were:

1. Bonding achieved at the appliance with the appliance grounded using the 14 AWG bare copper wire contained in a 14/2 Romex cable.

2. Bonding achieved at simulated service entrance bonding connection with an AWG 6 copper wire.

3. Bonding achieved with the 14 AWG bare copper wire in a 14/2 Romex cable at the appliance and an AWG 6 copper wire at the service entrance bonding connection.

The application of simulated lightning currents to the CounterStrike in each of the three bonding configurations, at a minimum of 4.76 Coulombs, did not puncture the stainless steel core. These test results show that using an additional 6 AWG grounding wire per IFGC 310.1.1 has no discernable effect on the ability of the CounterStrike to withstand lightning currents.

3.0 TEST EQUIPMENT

A list of the calibrated equipment, including calibration dates, can be found in Table 1. All measurement equipment furnished by Lightning Technologies, Inc. is calibrated by a commercial calibration agency in accordance with the requirements of the second edition of ISO/IEC 17025, *General Requirements for the Competence of Testing and Calibration Laboratories*, and/or ANSI/NCSL Z540-1-1994, *Calibration Laboratories and Measuring and Test Equipment-General Requirements*, using standards traceable to the National Institute of Standards and Technology.

Table 1 - Test Equipment List

Description	Manufacturer	Model No.	Serial No.	Calibration	
				Date	Due Date
Pearson	Attenuator	A10	99671	25 Jun 09	25 Jun 10
	Current Probe	1423	118521	16 Jan 09	16 Jan 10
Tektronics	Oscilloscope	TDS3032B	B033378	12 Oct 09	12 Oct 10
			B015906	11 Mar 09	11 Mar 10
T&M Research	Current Viewing Resistor	F-1000-4	8208-8	14 Jan 09	14 Jan 10
		W-2-01-4S	9039	14 Jan 09	14 Jan 10

4.0 TEST SETUP AND PROCEDURES

An approximately 48 inch long ¾" CounterStrike test article was installed 1/8th inch underneath a rod electrode which was connected to the output of a lightning waveform generator. One end of the CounterStrike test articles was attached to a sheet metal chassis with a standard OmegaFlex fitting and appliance termination. The bonding of the CounterStrike to the lightning generator return (copper bench) was achieved using either:

1. The bare copper wire from a 10 foot length of 14/2 Romex cable, to simulate the electrical bonding of the appliance,

2. A 10 foot long AWG 6 copper wire that was clamped to a CounterStrike fitting, to simulate a service entrance ground connection, or

3. Both the 14/2 Romex bare copper wire ground and the AWG 6 copper wire ground.

Figures 1 through 3 show the general test set-up and the bonding configurations.

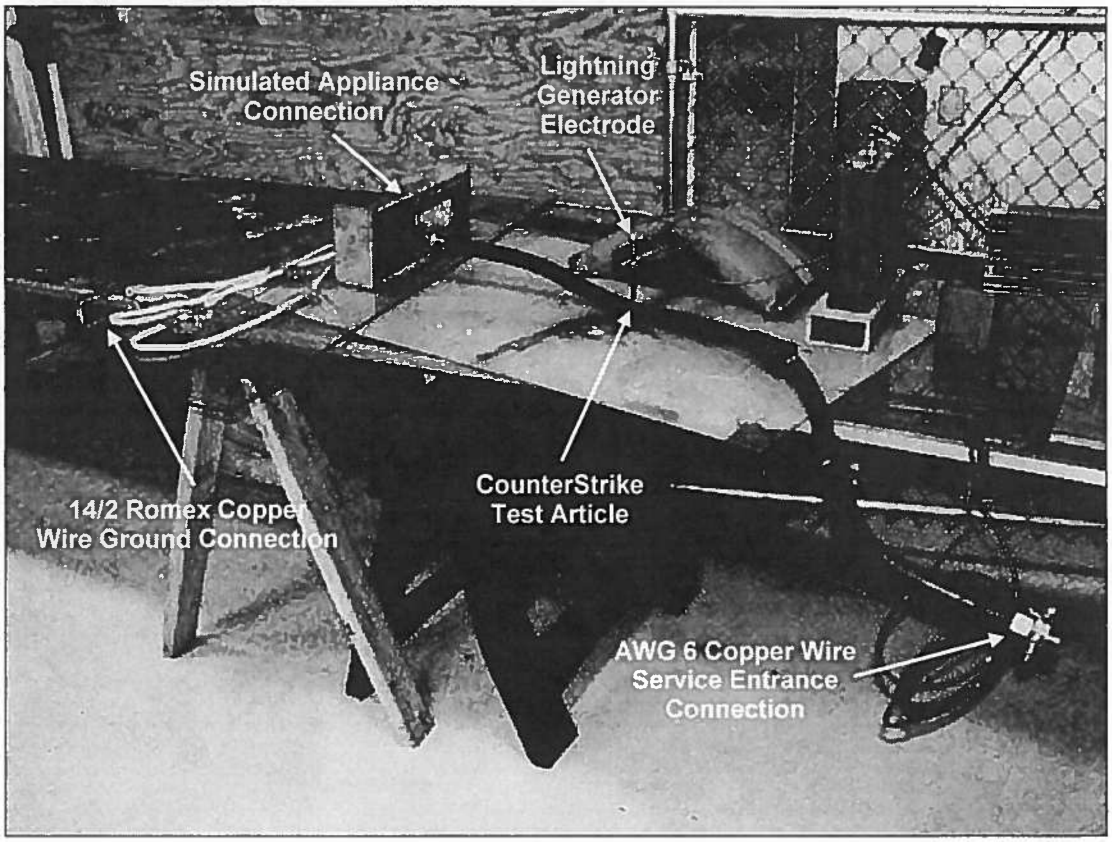

Figure 1 – Test Set-up

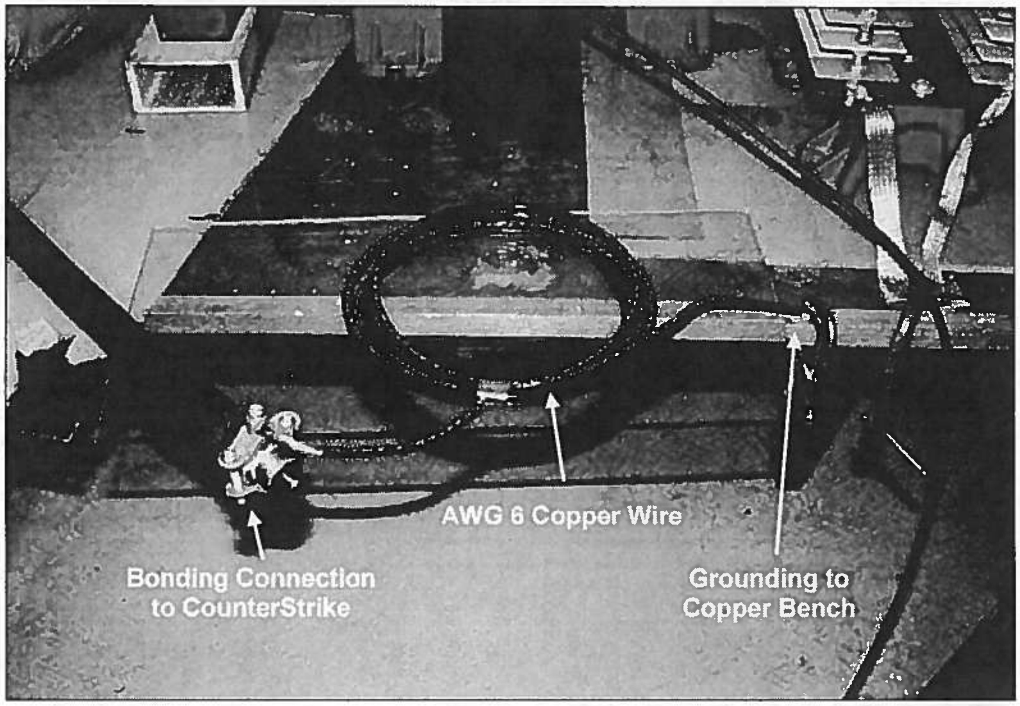

Figure 2 – AWG 6 Service Entrance Simulation

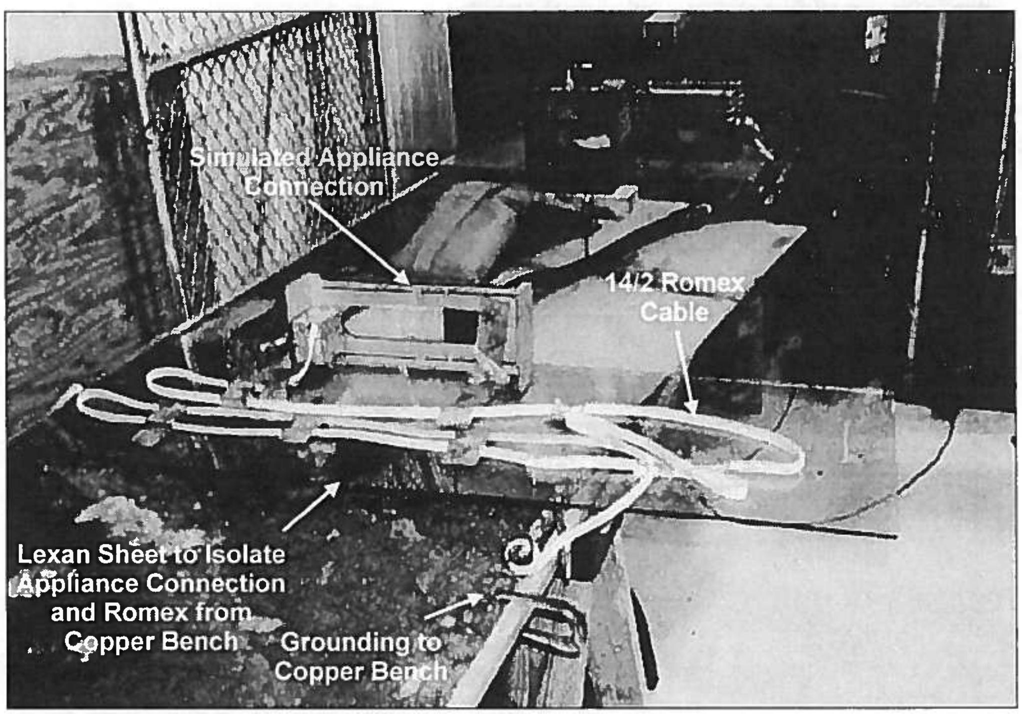

Figure 3 – 14/2 Romex Appliance Grounding Simulation

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The lightning waveform generator was composed of capacitors, a waveshaping resistive/inductive network, and a switch that were connected to the rod electrode. The capacitance was charged to a pre-determined value by a high voltage power supply and then discharged through the waveshaping network and the test article. A current probe and an oscilloscope measured the current through the test article. The oscilloscope was also used to calculate the applied charge to the test article (coulombs). A pictorial description of the test setup is shown in Figure 4.

Figure 4 – Test Generator Set-up

Seven tests of the ¾" CounterStrike piping were performed, consistent with the ICC-ES Listing Criteria LC1024. Three (3) tests were performed using the 14 AWG copper wire as the ground, two (2) tests with the 6 AWG wire as the ground, and two (2) tests using both. All tests were conducted at a level exceeding 4.5 coulombs and 1000 amperes.

5.0 TEST RESULTS

A summary of the current discharge testing is provided in Table 2. Examples of the damage created by the current discharges are contained in Figures 5 through 7.

Appendix A contains the current and coulomb waveforms recorded during the current discharge testing.

Table 2 – Test Results

Test No.	Product	Grounding Configuration	Generator Charge (kV)	Peak Current (kA)	Applied Coulombs (C)	Result
1	FGP-CS-750	14 AWG	16	1.39	6.0	No Puncture in Core
2	FGP-CS-750	6 AWG	16	1.39	5.24	No Puncture in Core
3	FGP-CS-750	Both	16	1.37	5.68	No Puncture in Core
4	FGP-CS-750	14 AWG	14.5	1.25	5.2	No Puncture in Core
5	FGP-CS-750	14 AWG	14.5	1.25	5.28	No Puncture in Core
6	FGP-CS-750	6 AWG	14.5	1.25	4.76	No Puncture in Core
7	FGP-CS-750	Both	14.5	1.23	5.12	No Puncture in Core

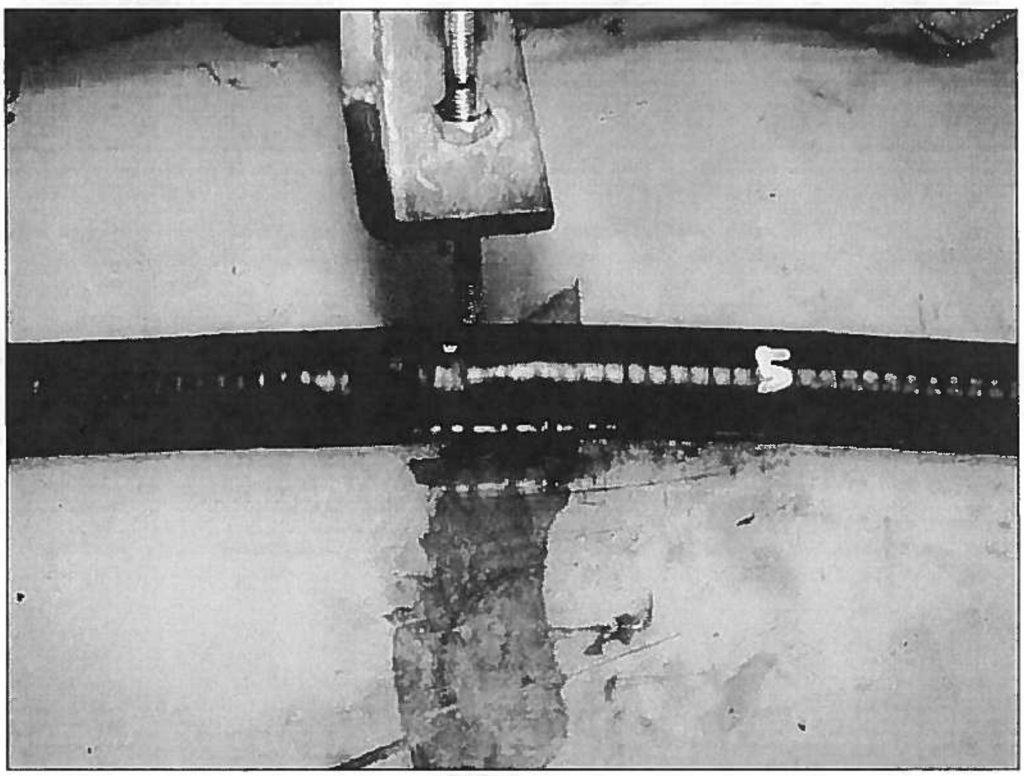

Figure 5 - Post-Test Damage to CounterStrike Grounded with 14/2 Romex Bare Copper Wire Only (Test 5)

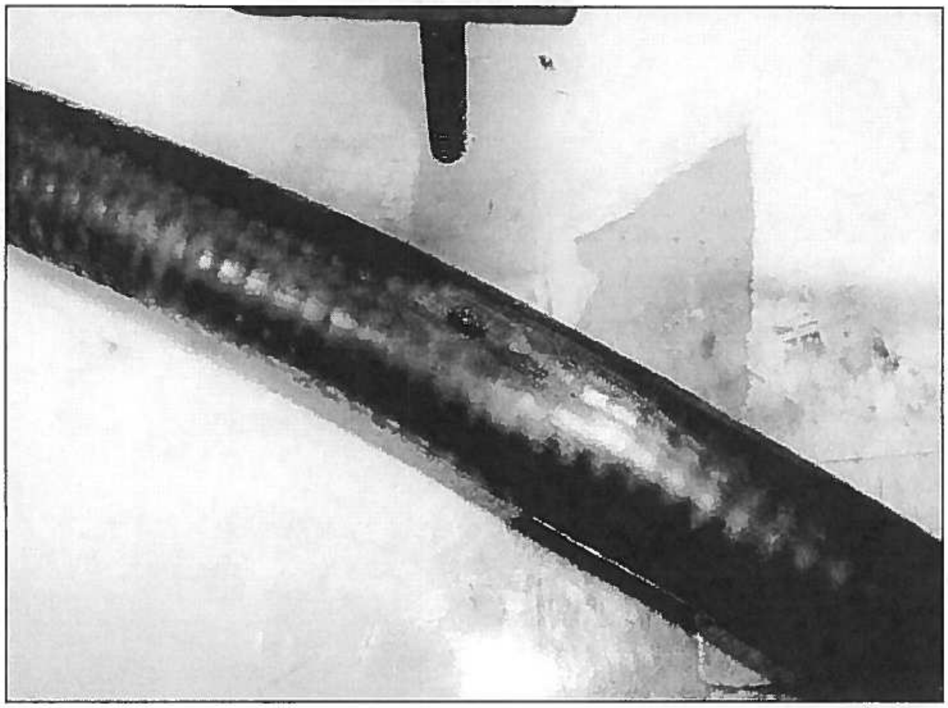

Figure 6 - Post-Test Damage to CounterStrike Grounded with AWG 6 Copper Wire Only (Test 6)

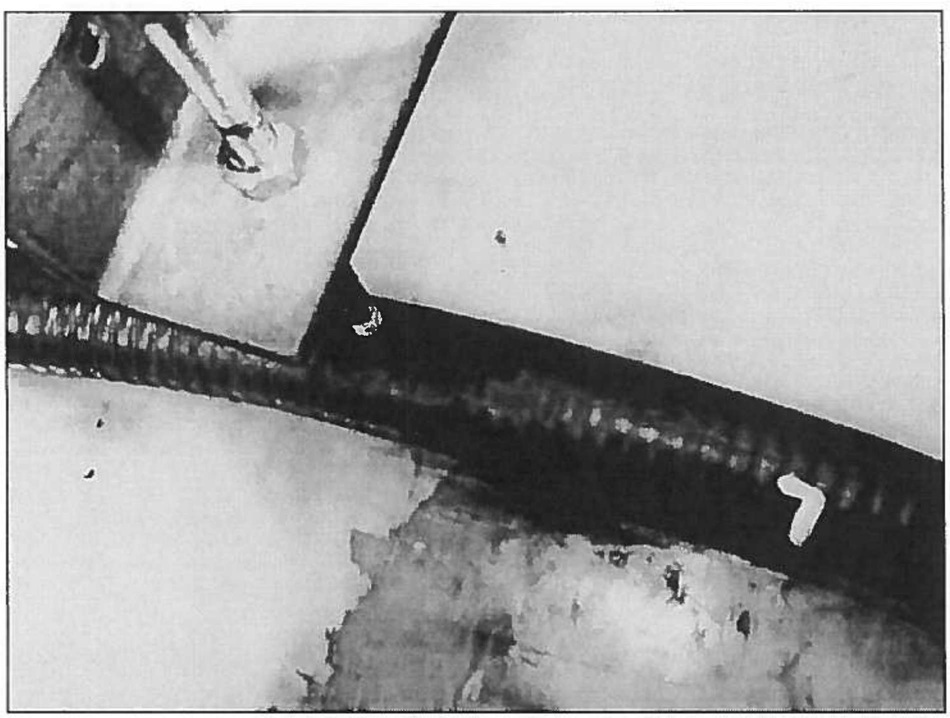

Figure 7 - Post-Test Damage to CounterStrike Grounded with AWG 6 Copper Wire and 14/2 Romex Bare Copper Wire (Test 7)

APPENDIX A

Applied Current and Coulomb Oscillograms

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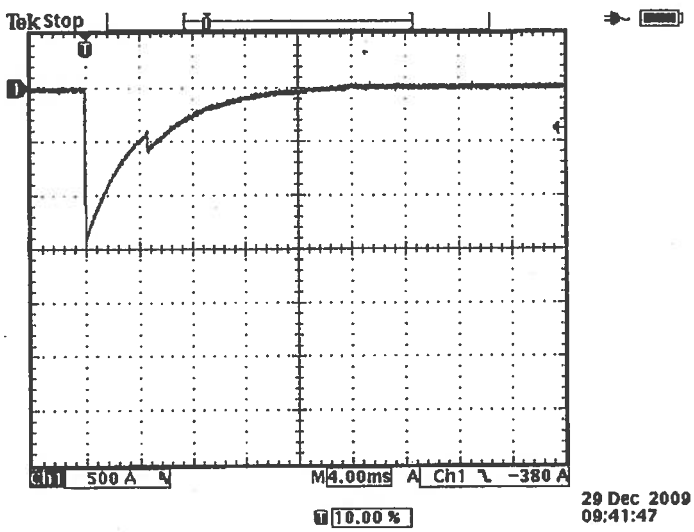

LIGHTNING TECHNOLOGIES, INC.
10 Downing Industrial Parkway
Pittsfield, MA 01201 USA
Ph. 413-499-2135 FAX -2503
Email: lti@lightningtech.com

Test No. 1

☒ Channel 1	☐ Channel 2	☐ Channel 3	☐ Channel 4
Voltage/Current	Voltage/Current	Voltage/Current	Voltage/Current
Peak 1.39 KA	Peak ______	Peak ______	Peak ______
Scale ______	Scale ______	Scale ______	Scale ______

REMARKS: 6 C

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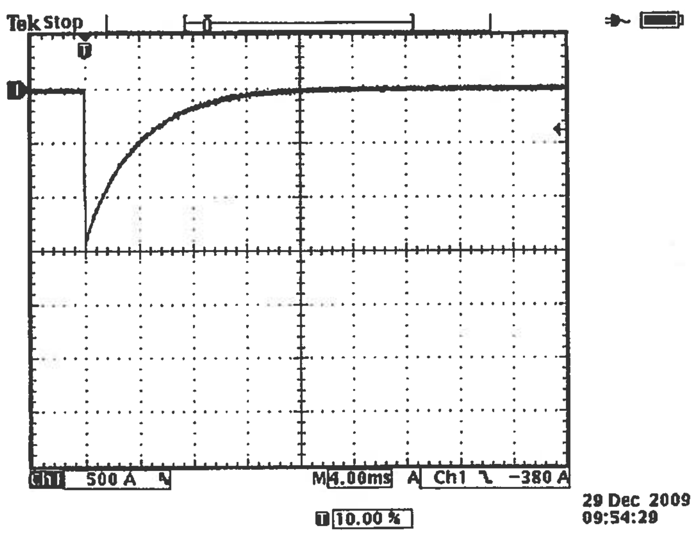

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Pittsfield, MA 01201 USA
Ph. 413-499-2135 FAX -2503
Email: lti@lightningtech.com

Test No. 2

☒ Channel 1	☐ Channel 2	☐ Channel 3	☐ Channel 4
Voltage/Current	Voltage/Current	Voltage/Current	Voltage/Current
Peak 1.39 KA	Peak ________	Peak ________	Peak ________
Scale ________	Scale ________	Scale ________	Scale ________

REMARKS: 5.24C

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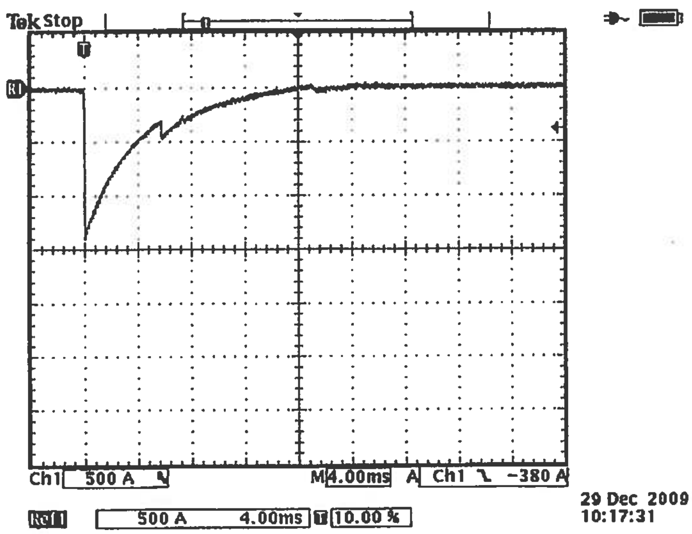

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Pittsfield, MA 01201 USA
Ph. 413-499-2135 FAX -2503
Email: ltl@lightningtech.com

Test No. 3

☒ Channel 1	☐ Channel 2	☐ Channel 3	☐ Channel 4
Voltage/Current	Voltage/Current	Voltage/Current	Voltage/Current
Peak 1.37KA	Peak ____	Peak ____	Peak ____
Scale ____	Scale ____	Scale ____	Scale ____

REMARKS: 5.68c

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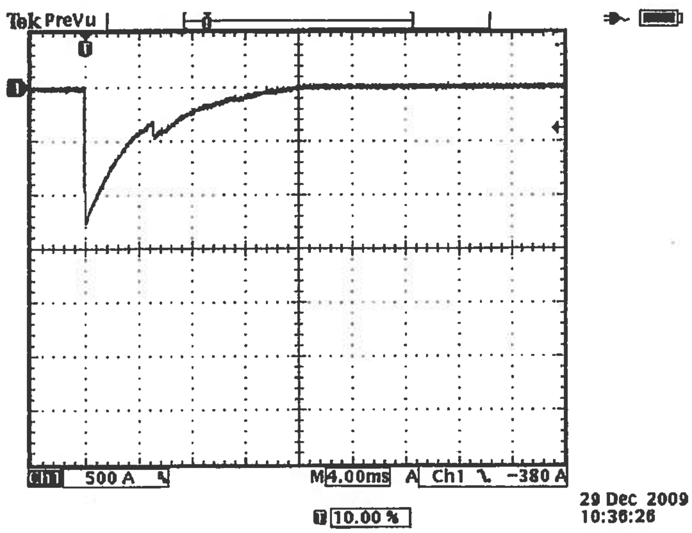

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Pittsfield, MA 01201 USA
Ph. 413-499-2135 FAX -2503
Email: lti@lightningtech.com

Test No. 4

☒ Channel 1
Voltage/Current
Peak 1.25 KA
Scale

☐ Channel 2
Voltage/Current
Peak
Scale

☐ Channel 3
Voltage/Current
Peak
Scale

☐ Channel 4
Voltage/Current
Peak
Scale

REMARKS: 5.2 C

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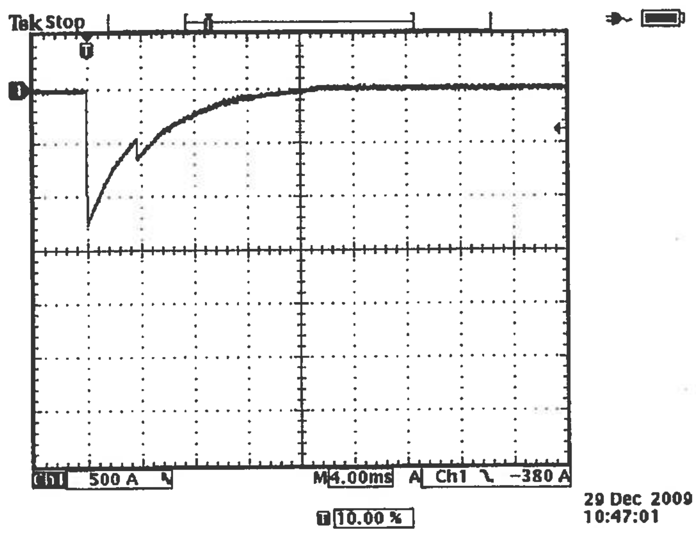

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Pittsfield, MA 01201 USA
Ph. 413-499-2135 FAX -2503
Email: lti@lightningtech.com

Test No. 5

☒ Channel 1	☐ Channel 2	☐ Channel 3	☐ Channel 4
Voltage/Current	Voltage/Current	Voltage/Current	Voltage/Current
Peak 1.25 kA	Peak ______	Peak ______	Peak ______
Scale ______	Scale ______	Scale ______	Scale ______

REMARKS: 5.28 C

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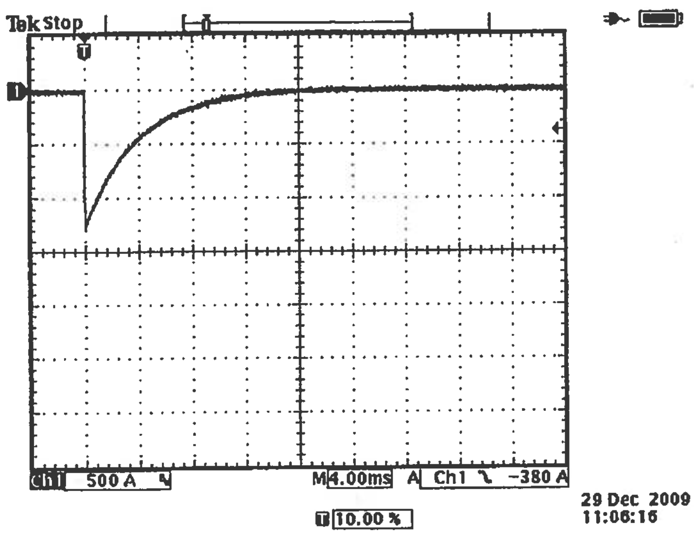

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10 Downing Industrial Parkway
Pittsfield, MA 01201 USA
Ph. 413-499-2135 FAX -2503
Email: ltl@lightningtech.com

Test No. 6

☒ Channel 1	☐ Channel 2	☐ Channel 3	☐ Channel 4
Voltage/Current	Voltage/Current	Voltage/Current	Voltage/Current
Peak 1.25 KA	Peak ______	Peak ______	Peak ______
Scale ______	Scale ______	Scale ______	Scale ______

REMARKS: 4.76C

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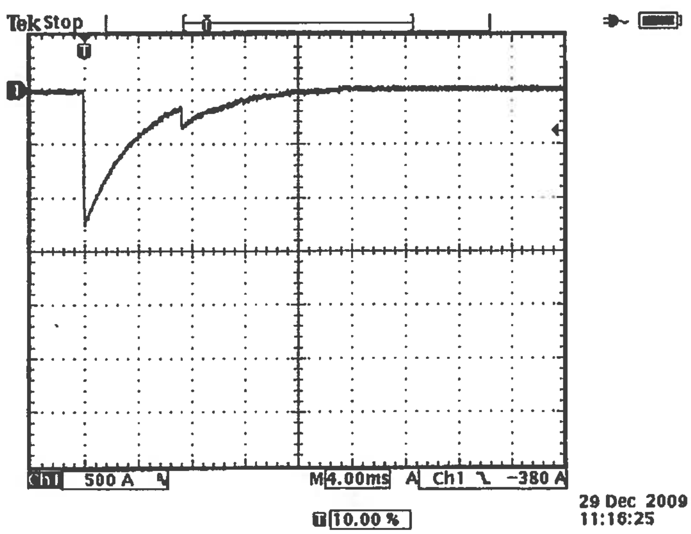

LIGHTNING TECHNOLOGIES, INC.
10 Downing Industrial Parkway
Pittsfield, MA 01201 USA
Ph. 413-499-2135 FAX -2503
Email: ltl@lightningtech.com

Test No. 7

☒ Channel 1	☐ Channel 2	☐ Channel 3	☐ Channel 4
Voltage/Current	Voltage/Current	Voltage/Current	Voltage/Current
Peak 1.23 kA	Peak ________	Peak ________	Peak ________
Scale ________	Scale ________	Scale ________	Scale ________

REMARKS: 5.12 c

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Residential Lightning Fires in the USA: Electrical Arcs and Fuel Gas Leaks

Michael F. Stringfellow, *Senior Member, IEEE*

Abstract— **This paper presents evidence that a major cause of residential lightning fires is electrical arc fault current. Such arc fault currents are a common result of both direct and indirect lightning. These faults result from lightning overvoltage damage to the insulation of electricity supply conductors and appliances. Many of these overvoltages appear to be caused by indirect lightning strikes and a small fraction of these events also result in damage to fuel gas systems, especially thin metallic flexible gas lines. Fuel gas leaks resulting from this electrical damage may contribute to the fire hazard. The absence of any lightning protection on residences with exposed metallic roof penetrations is considered a major factor.**

Index Terms— **Arc discharges, bonding, electric breakdown, fires, insulation, lightning, wiring**

I. Introduction

A companion paper [*1*] discussed an overview of the residential lightning fire problem in the USA. It concluded that, contrary to widespread popular supposition, many lightning fires result not from direct ignition by the electrical currents of a lightning strike, but from damage to the electrical system of the building. Evidence also indicated that some fraction of fires, possibly even a majority, is caused by indirect lightning strikes. These latter events occur when lightning strikes the ground nearby and overvoltages and overcurrents are induced on metalwork in the building by secondary processes.

These conclusions emerged following the author's investigations of a number of residential lightning fires involving damage to gas pipes and attic-mounted electrical equipment. The gas pipe damage generally took the form of small holes in thin flexible tubular steel gas lines. The majority of the observations involved Corrugated Stainless Steel Tubing (CSST), which is designed to replace the more generally utilized rigid steel pipes. Some lightning-related holes also occurred on the short flexible appliance connectors that have similar construction to CSST.

Manuscript received June 8, 2012

M.F. Stringfellow is with PowerCET Corporation, Scottsdale, AZ, 855255 USA (phone 480-556-9510; e-mail mikes@powercet.com)

Damage to these gas lines has been observed for over a decade and the accepted explanation is that the holes are caused by the electric currents of lightning discharges [*2*].

This paper examines the evidence for the source of these holes and the reasons that the author believes that the majority cannot result directly from lightning. The author further concludes that the many residential lightning fires result from electrical system damage and that fuel gas fires are likely a small subset of these.

II. Nature of Damage to Gas Lines

Three types of electrical damage to thin flexible steel gas lines have been reported in the literature, namely:

1. Severe damage at an appliance connector from electrical fault currents.
2. Arc damage from contact with energized insulated electrical conductors.
3. Arc damage associated with direct or indirect lightning strikes.

The first type was identified in the short flexible connectors to appliances and occurred in residences in which the electrical power system was improperly grounded or where overcurrent protection devices malfunctioned. The authors of this investigation [*3*] comment "The fires that occurred in these instances were all brought about because of electrical faults and yet none of these fires would be considered to be "electrical" in nature."

The second type occurs where energized electrical power conductors contact the stainless steel pipe directly. These have occurred where the insulating jackets of the conductor and CSST have been compromised, for example by mechanical damage or fire. Some proportion of CSST holes in lightning-caused fires likely result from this cause and not from lightning currents.

The third type has been more widely observed on longer runs of CSST, although incidents involving shorter appliance connectors have been noted. In these cases, one or more holes are created in CSST lines that are evidently the result of a high-voltage electrical breakdown from the metal tube to a nearby conductor through the insulating jacket.

Fig. 1 shows an example of a pair of holes caused by a lightning event in a 1/2inch CSST line. Lightning-location data verified that two strokes of a multiple stroke flash terminated on or near the structure.

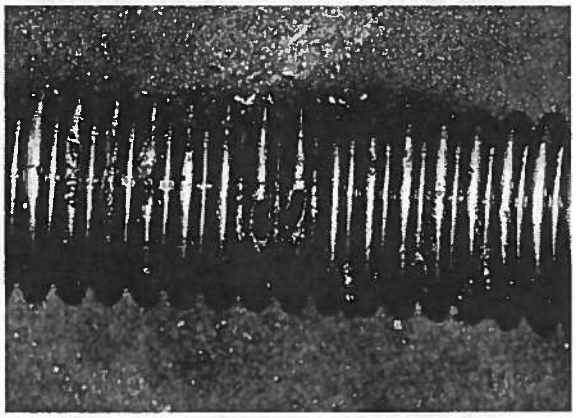

Fig. 1: Damage to CSST from two-stroke lightning flash

Standards bodies and others have devoted considerable attention over the past decade to the issue of arc damage to CSST [*4*]. The focus of this attention has generally been on the inability of CSST to withstand lightning currents flowing in residences that are unprotected against lightning. This is despite the fact that very little is known about the magnitude or waveshape of lightning currents inside buildings or the way currents may be distributed between the various services. Furthermore, there are no known standards or requirements for any building services (electricity supply, gas lines, telephone or water pipes and TV cables) to carry or withstand lightning currents inside unprotected structures.

III. Arc-Induced Holes in Thin Metal

Both CSST and some shorter flexible appliance connectors are manufactured from corrugated stainless steel having a wall thickness in the order of 0.25mm. The earliest tests on puncture of metals under electrical arc conditions were carried out by McEachron and Hagenguth in an investigation into the effects of lightning discharges on aircraft materials [*5*] [*6*]. The results of these studies were that puncture was most determined by the electrical charge flowing in the arc and the metal thickness, and was not strongly dependent on the type of metal. In order to create a hole, an electrical arc must provide sufficient energy to melt the metal. When an electrical arc terminates on metal, the energy dissipated at the interface is proportional to the voltage across the arc/metal interface, the magnitude of the current and its duration. Since the interface voltage between an arc and a specific metal is nearly constant, the energy dissipated in an arc at the metal termination for a given waveshape is very nearly proportional to the total charge transfer (Fig. 2).

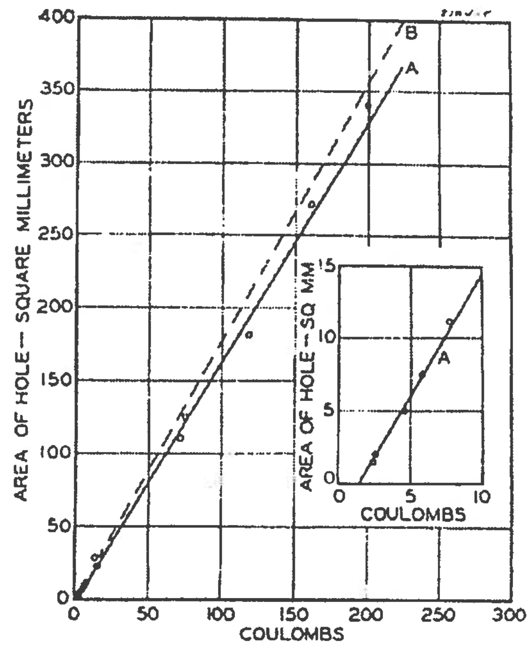

Fig. 2: Relation between coulombs in the arc and resultant area of holes burned in sheets of (A) 15 mil galvanized iron and (B) 20 mil copper [*5*]

For stainless steel of ten thousandths of an inch thickness (10mil or 0.25mm), which is very similar to the wall thickness of CSST, Hagenguth [*6*] derived the following formula for the area of hole melted (A) in square millimeters versus the charge carried by the discharge (Q) in coulombs, as a function of the metal thickness (t) in mils:

1. $A=25.3Qt^{-0.9}$

For CSST tube having a wall thickness of 10mil, this equation may be reduced to:

2. $A=3.19Q$

More recent measurements carried out on CSST with millisecond lightning waveforms [*7*] show that simulated lightning discharges having charges of 0.12 C are the minimum necessary to create a small hole and that for discharges of 0.15 C, the hole is approximately 1/32 inch (0.8 mm) in diameter. This hole has an area of just less than 0.5 square millimeters, in close agreement with the above equation (2) derived from Hagenguth's tests.

The author also conducted a series of tests on thin aluminum foil using an industry-standard 8x20µs lightning surge test waveform [*8*]. The results of these tests broadly confirmed Hagenguth's results but also showed that there was a minimum current below which a hole was not created. Above this threshold, the relationship between hole size and both peak current and impulse charge was linear (Fig. 3).

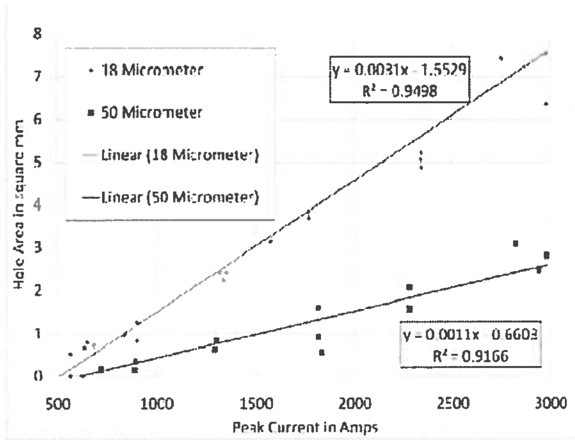

Fig. 3: Relation between hole size and electrical impulse current in arcs to thin aluminum foils.

For this range of thickness and lightning current waveforms, the observed holes did not correspond exactly to Hagenguth's equation 1. The charge transfer for the 8x20µs waveform used for these tests was measured at approximately $1.7x10^{-5}$ C per ampere peak, a little below the theoretical value of $1.746x10^{-5}$ C per amp.

Linearly extrapolated to metal thickness of 0.25mm, the calculated relationship between hole area (A) and charge (Q) from the author's data is given by:

3. $A=1.26Q-0.12$

This predicts somewhat smaller holes than would be expected from Hagenguth's data, summarized in equation 2 above. It is not known if this is because of the difference in waveform or the use of thinner metal film. However, this observation is consistent with more recent studies that show smaller holes to result from shorter duration waveforms for the same charge transfer.

These studies [*9*] [*10*] [*11*] have expanded on this earlier work by using both shorter and longer test waveforms. The later data shows that Hagenguth's data are valid for the waveform used, but that the charge required to puncture thin metal also depends on the duration of the arc. Very short and very long duration currents require higher charges to puncture a metal of given thickness than those of moderate duration. The duration for which the charge required to create a puncture hole is minimum lies between 0.01 and 0.1 seconds (Fig. 4).

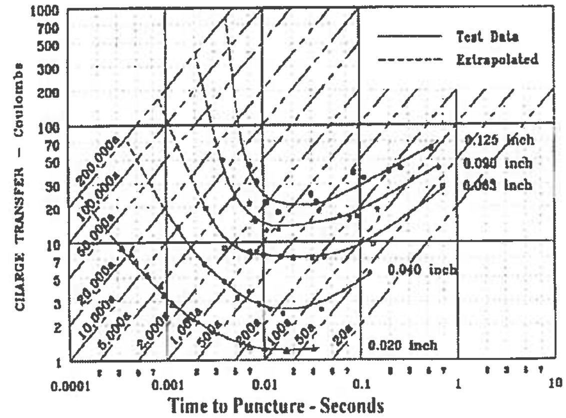

Fig. 4: Relation between coulombs in the arc and time to puncture thin metal sheets of various thicknesses [*11*]

IV. CSST Lightning Damage

CSST consists of a thin flexible stainless steel tube that is encased in a plastic dielectric covering. Thus, the creation of an electric arc to the metal tube requires a sufficiently high voltage to breach this dielectric covering. For short impulsive (lightning) waveforms, this voltage varies between about 10kV and 50kV among the various commercially available pipes [*7*]. It is clear that for lightning to create an arc to CSST, sufficient voltage is required to jump not only between the gas pipe and a nearby conductor, but also to penetrate the dielectric jacket.

The damage that occurs to CSST from lightning strikes consists of one or more holes that appear to be the result of a high-voltage arc through the insulating jacket to a nearby conductor. The size of the holes varies from a small pin hole up to several square millimeters. Multiple holes, including adjacent holes, are not uncommon in a single event, as shown above in Fig. 1.

The widely-held assumption by fire investigators, engineers and manufacturers has been that these holes result directly from the flow of lightning currents, that is, a source external to the building. However, assessments of the available electrical energy to account for the observed size of holes has required assumptions of unusually large currents from lightning and that these flow almost exclusively along the damaged gas pipe. A widely quoted source for the electrical energy is the observation of long duration (continuing) currents between the strokes of a multiple-stroke lightning flash.

The evidence in most cases of lightning-related damage to CSST does not however support these assumptions for the following reasons:

1. Approximately 80% of the incidents are described as being caused by "indirect" lightning strikes – that is a strike to earth or an object nearby, but not directly to the structure.

2. Adjacent multiple holes in CSST pipes are not uncommon and these holes are often about the same size.

3. Continuing currents occur only once per lightning flash.

The significance of these observations is as follows:

1. Indirect lightning strikes involve the injection of currents and voltages through a number of different mechanisms on electrical conductors in a structure. All of these mechanisms can produce voltages high enough to cause a flashover between a CSST line and an adjacent conductor through its insulating jacket, but most are short duration and contain insufficient energy to rupture the steel itself (Fig. 5).

2. Adjacent electrical arcs cannot be simultaneously sustained because of the non-linear characteristics of the arc channel resistance. Adjacent holes must therefore have occurred serially, possibly from successive overvoltages resulting from strokes of a multiple-stroke lightning flash.

   Multiple adjacent holes in CSST have also been reported from contact with fire-damaged power system conductors. It is presumed that this is a similar mechanism involving successive arcs through melted or burned insulation.

3. Continuing currents can only explain single large holes where a direct lightning strike to a structure is confirmed. Injection of continuing current into a structure from an indirect strike is unlikely.

For these reasons, the author has sought an alternative explanation for this type of damage to CSST pipes.

V. Alternative Explanation of CSST Lightning Damage

The existence of adjacent holes of about the same size (Fig. 1) suggests that the same amount of electrical energy is required to produce each hole. It is extremely unlikely that subsequent strokes of a multiple-stroke lightning flash have similar current magnitudes and durations. Furthermore, it is virtually unknown for a direct lightning strike to produce two or more instances of continuing current [*12*]. Indirect lightning strikes inject much lower currents than direct strikes and most coupling mechanisms result in current magnitudes and durations orders of magnitude too small to rupture CSST (Fig. 5).

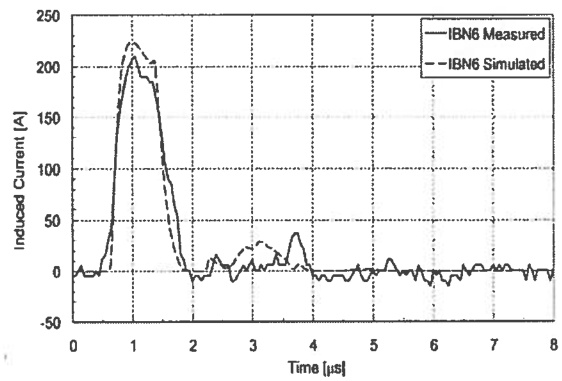

Fig.5: Transient current induced on overhead power line by nearby lightning [*13*]

The electrical power system in the structure is a local source of energy that is more likely to provide similar energy in multiple flashover arcs. Flashovers involving electrical power follow current have the same source voltage and circuit impedance. Power fault currents are therefore much more likely to result in holes of similar size than lightning currents.

Estimates of the magnitude of energy required to melt the holes of the observed sizes provides further support for this proposed explanation. Based on equations 2 and 3 from the previous sections, an arc discharge of one coulomb creates a hole of area of about 1-3 square millimeters, or approximately 1-2mm in diameter.

The typical explanation for a hole of such size would be a lightning continuing current of magnitude 10 amperes and duration 100 milliseconds. However, the same charge can be delivered by a half-cycle 60Hz fault current of 120 A RMS (170 A peak). This magnitude of fault current is well within the range expected for shorted conductors on typical branch circuits in residences. Furthermore, the time for a standard overcurrent circuit breaker to operate is longer than the time for a power-fault arc to burn a hole in CSST.

Typical 15-amp rated circuit breakers for residential use have rated operation times for a current of 120-amp RMS, which is eight times nominal current rating, in the range between 0.5 second and 3 seconds (Fig. 6).

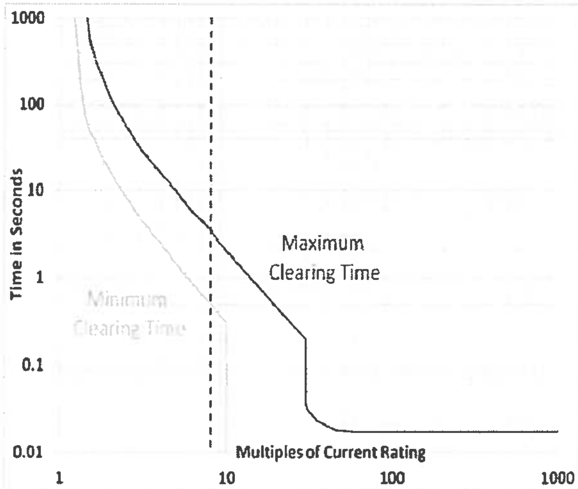

Fig. 6: Typical time-current curve of residential circuit breaker

Recent preliminary laboratory tests by the author and others show a 60 Hz power fault arc from the power conductor of a typical 120-volt system to a CSST pipe will create millimeter-sized holes within one or two half-cycles. In these tests, the arc current has been observed to be either limited by the opening of the power system circuit breaker or to self-extinguish. The latter permits multiple flashover-induced arcs from the sequential strokes of a multiple-stroke lightning flash while the power system remains energized, which is consistent with the observation of multiple holes.

VI. Electrical Faults

The insulation withstand of wiring insulation to lightning overvoltages is in the range of 4kV to 6kV, or about six times lower than the average withstand of the insulating jacket of CSST (~30kV). Since the incidence of lightning-induced overvoltages is approximately log-normal (Fig. 7), the incidence of 5kV magnitude surges will be approximately ten times higher than the incidence of 30kV surges. Consequently, the frequency of flashover of power systems will be much higher than flashover through CSST jackets.

Power-fault arcs through damaged or overstressed electrical insulation will therefore be much more frequent than arc damage to CSST pipes.

A significant exposure in residences is heating, ventilation and air-conditioning equipment (HVAC). Flues from gas heaters in such equipment and from chimneys are usually metallic.

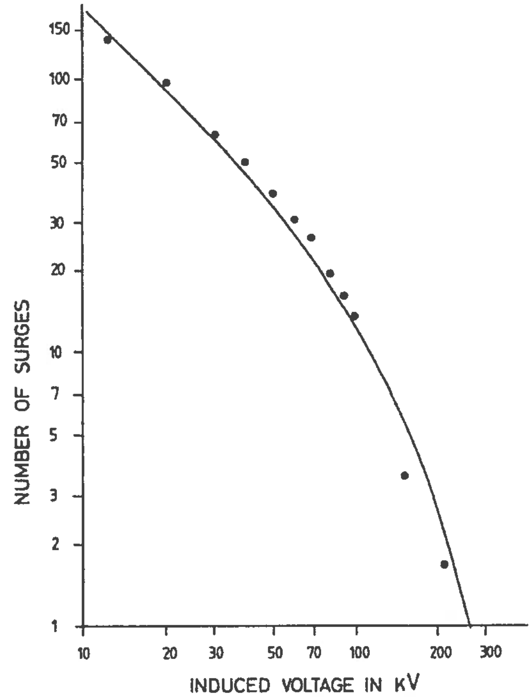

Fig. 7: Measured incidence of lightning-induced overvoltages on an overhead distribution line [*14*]

These can readily inject lightning currents into building services from both direct and severe indirect strikes, frequently compromising attic-mounted equipment.

Data from the National Fire Incident Reporting System (NFIRS) show that fires involving electrical systems are very prevalent [*15*] and that this is especially serious when such fires occur in attic spaces [*16*].

According to this report on residential attic fires:

- An estimated 10,000 attic fires in residential buildings occur annually in the United States, resulting in an estimated average of 30 deaths, 125 injuries, and $477 million in property damage.
- The leading cause of all attic fires is electrical malfunction (43 percent).
- The most common heat source is electrical arcing (37 percent).
- Natural causes (mostly lightning) account for 16% of the fires

The author's examination of data from insurance claims of lightning fire damage to residences suggests that as many as 55% of the incidents may be ignited by lightning damage to the electrical system rather than directly by the lightning itself (Fig. 7). This is particularly intriguing given the high incidence of reports of "indirect" lightning in the CSST incidents previously referenced. The author considers that NFIRS reports on the material first ignited may include materials ignited by electrical faults.

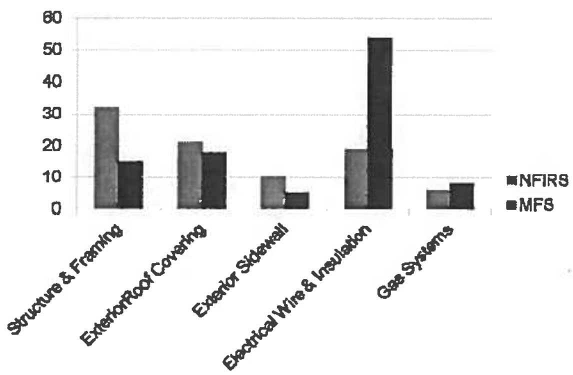

Fig. 7: Material ignited in residential lightning fires

The conclusion is therefore that a significant proportion of lightning-induced fires are caused not by the electrical energy of the lightning itself, but by overvoltage disruption to electrical insulation. This disruption can readily occur from indirect lightning strikes by secondary mechanisms that may not be readily ascribed to lightning. The observation of what is clearly electrical arc damage to CSST from indirect lightning strikes is a very strong indicator that such disruption does occur.

VII. Discussion

The evidence strongly suggests that arc damage to thin gas pipes cannot solely be attributed to the electrical energy from lightning. The author proposes that the initiation of electrical system power fault current by high-voltage low –current lightning surges is a likely alternative explanation.

Since damage to the electrical insulation of electrical wiring occurs at much lower voltages than damage to gas pipes, it seems likely that many residential fires in the USA may result from electrical arcing faults caused by lightning overvoltage. This faults result in the flow of power currents through combustible materials, including the electrical insulation and structural components, such as roofing, siding and dry wall. A fraction of these overvoltage incidents causes damage to gas pipes, including arc-induced holes. Release of fuel gas through damaged pipes can start or exacerbate existing fires.

The author believes that significant contributors to this problem are the increasing installation of attic-mounted HVAC equipment that frequently utilizes metallic flues penetrating the roof and gas fireplaces connected to metallic chimney liners and caps. These metallic roof penetrations facilitate the injection of lightning currents into services in the residence, including the electrical, gas and water systems. Consequential damage to these installations appears all too common and appears to be particularly hazardous in attic spaces.

There are currently no national codes in the USA that mandate the installation of lightning protection on residences. The one relevant standard, NFPA 780 "Standard for the Installation of Lightning Protection Systems" [*17*] is voluntary and protection on residences is rare (3% to 5% of structures). Where lightning protection is installed, the requirements for bonding of metallic services and structural components and the installation of surge protective devices are met. The author is unaware of any residential lightning fires that occurred on a residence properly protected in accordance with this standard.

The National Electrical Code [*18*], which considers primarily electrical safety and not lightning hazards, has no requirements for directly grounding metallic roofs or roof projections, such as vents and chimney flues. In the absence of a lightning protection system, vulnerable metal roofs and metallic roof projections remain a significant lightning hazard.

Some success in mitigation of electrical fires triggered by lightning has been reported in countries where ground-fault protection is required on all circuits in residences. It appears possible that similar benefits may be provided by wider application of either ground fault or arc fault circuit breakers.

VIII. Conclusions

Mitigation of these electrical arc fires induced by lightning may be achieved by the following actions:

1. Provide a lightning protection system installed in accordance with NFPA 780. Alternatively, directly ground to the building earth electrode all metal roofs, chimney flues and metallic roof penetrations, especially those that are connected to equipment in the attic space.

2. In structures not equipped with a lightning protection system, provide equipotential (low-impedance) bonding between all metallic services where they enter the building. This bonding should include not only the power system, communications lines and water pipes, but also metallic gas pipes on the service side of the meter.

3. Install properly-rated surge protective devices on power system and other vulnerable metallic services entering or leaving the building.

4. Protect electrical circuits likely to suffer lightning–induced flashover by either a ground-fault interrupter or arc fault circuit interrupter.

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Michael F. Stringfellow (M 1984–SM 2010) received the degree of B.Sc.(Hons) in physics from the University of London in 1966 and the degree of Ph.D. in physics from the University of Durham in 1970 for research into atmospheric electricity.

His early work was at the Electricity Council Research Centre in England on problems of lightning protection of power systems and lightning tracking and warning. He moved to South Africa in 1976. There, he worked for the Electricity Supply Commission (Eskom) on lightning problems of power systems and for the South Africa Bureau of Standards on lightning protection of structures. He has lived and worked in the USA since 1985 and has held the position of Chief Scientist of PowerCET Corporation since 1994. In this position, he provides consulting, testing and research services on power systems, transient overvoltages and electromagnetic compatibility. His personal specialty is lightning hardening of commercial and industrial facilities, and lightning damage to structures and systems.

Dr. Stringfellow is a Fellow of the Royal Meteorological Society and has participated in Standards bodies in Britain, South Africa and the USA, including IEEE and IEC Committees. He has authored or co-authored over forty scientific or engineering publications and has one US patent. He is a registered Professional Engineer in Georgia.