

**Corrugated Stainless
Steel Tubing for Fuel Gas
Distribution in Buildings
and Concerns over
Lightning Strikes**

August 2007

Report Number: 5737-01_080307



*America's Housing Technology
and Information Resource*

Prepared by

The NAHB Research Center, Inc.
400 Prince George's Blvd.
Upper Marlboro, MD 20774
800-638-8556
Fax 301-430-6180
www.nahbrc.org

August 2007



About the NAHB Research Center...

The NAHB Research Center, Inc. is a subsidiary of the National Association of Home Builders (NAHB). The NAHB has over 225,000 members who build more than 80 percent of new American homes. The NAHB Research Center conducts research, analysis, and demonstration programs in all areas related to home building and carries out extensive programs of information dissemination and interchange among members of the industry and between the industry and the public.

Disclaimer

Neither the NAHB Research Center, Inc., nor any person acting in its behalf, makes any warranty, express or implied, with respect to the use of any information, apparatus, method, or process disclosed in this publication or that such use may not infringe privately owned rights, or assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this publication, or is responsible for statements made or opinions expressed by individual authors.

Corrugated Stainless Steel Tubing for Fuel Gas Distribution in Buildings and Concerns over Lightning Strikes

August 2007

Executive Summary

As the result of recent legal actions related to a potential for physical damage caused by lightning, manufacturers of corrugated stainless steel tubing (CSST) agreed to a settlement that, in part, places new requirements on the installation of their gas piping products. This paper provides background information on CSST and the actions taken by the manufacturers to address these concerns.

In summary, the primary issue is safeguarding against an electric potential in metallic piping. In the case of proximity lightning, a high voltage can be induced in metallic piping that may cause arcing; and for CSST there is concern that arcing may cause perforation of the CSST wall and therefore cause gas leakage. The fuel gas code, electric code, plumbing code, product standards, and manufacturer installation instructions have different methods of providing dissipation of electrical energy through techniques called bonding and grounding. Since the codes, product standards, and installation requirements are not harmonized, builders and contractors may find differing and possibly conflicting requirements. Generally, the local jurisdiction having authority and code official will rely upon the manufacturer's installation recommendations in lieu of other requirements. Currently, the CSST manufacturers' installation requirements are the most stringent compared to the codes and standards. Users of CSST are advised to abide by the manufacturer's instructions and also coordinate with local code officials to avoid inspection delays due to conflicting requirements.

Recently updated CSST manufacturer's installation instructions now include the requirement to directly bond the CSST system to the electrical system grounding system. The bonding attachment must be near the service entrance to the building and the connection must be made with a 6 AWG copper wire. This method of bonding will provide additional protection to the CSST system when it is energized by an indirect lightning strike. All CSST manufacturers have issued either Technical Bulletins or other documents to describe the new requirements. Although similar, these bonding requirements are currently not identical between the manufacturers. Manufacturers' installation instructions have undergone a series of changes since 1996 to reflect the impact of the prevalent construction practices at the time of their printing including modifications to the bonding requirements.

The new manufacturer bonding requirements deviate from current code language in both the National Electrical Code (NEC) and the National Fuel Gas Code (NFGC). These codes rely on the use of the equipment grounding conductor to provide the bonding means for the gas piping system. Over the past four code cycles (12 years),

the code coverage between these two codes has varied for several reasons. A proposal to modify the bonding requirements for CSST in the 2009 NFGC is currently under review, and the 2011 edition of the NEC will follow suit provided the NFGC proposal is accepted and published. In the meantime, state and local acceptance of the manufacturer's instructions is being addressed on a state by state basis on a much faster schedule.

1.0 Background

1.1 Overview

As the result of recent legal actions, manufacturers of corrugated stainless steel tubing agreed to a settlement that, in part, places new requirements on the installation of their gas piping systems. Although there were no findings of fact resulting from this legal action, these manufacturers have agreed to require a direct method of electrical bonding of their products to help reduce the potential for damage (caused by arcing) to their products when energized by indirect lightning strikes. This report describes the current situation within the institutional area of codes and standards and the approach taken by the manufacturers to institute these new bonding practices. The efficacy of the described bonding practices has not been evaluated. The acceptance of these methods within the national and state codes is currently being deliberated by the affected code governing bodies, and the results from these deliberations are uncertain at this time. Continued monitoring of the ongoing situation is advised.

1.2 CSST: A New Concept in Gas Piping

The 1988 commercial introduction of corrugated stainless steel tubing (CSST) to distribute natural and LP gas within and throughout residential and commercial buildings was welcomed by the gas industry as a cost-effective means to deliver their product to consumers. CSST piping systems gave plumbers and gas fitters an alternative approach to the use of other code-approved piping materials: Schedule 40 threaded, steel pipe, and copper tubing. However, CSST represented a major breakthrough in gas piping far beyond its obvious flexible physical characteristics. The departure from conventional practice was that for the first time the gas piping was treated as a complete system covered by a performance standard (the same way gas equipment is treated) and not as a material standard.

Traditional gas piping (steel pipe and copper tubing) is manufactured to material standards that dictate its physical properties and dimensional requirements. However, these national standards do not address how these piping products must perform as gas piping systems. The application of steel pipe as gas piping has been developed from field experience gathered through millions of residential installations over the past 100 years. These practices have been collectively promulgated into the National Fuel Gas Code or ANSI Z223.1 (NFGC). CSST was engineered from its conception as a

system consisting of tubing, fittings, manifolds, protective shields, and other accessories designed specifically as a gas distribution network.

Research sponsored by the Gas Research Institute (from 1983 to 1989) was used to develop and to support the creation of a nationally recognized standard for CSST systems. The initial standard was developed by the American Gas Association Laboratories in 1986, but was considered only a bench standard. It was eventually designated as AGA 1-87. This standard was ultimately transformed into an ANSI standard in 1991 and became known as ANSI/AGA LC-1-1991 "Interior Fuel Gas Piping System Using Corrugated Stainless Steel Tubing." Over the past 15 years, updating and improvements have been made to this standard such that today it is known as ANSI LC-1-2005 "Fuel Gas Systems Using Corrugated Stainless Steel Tubing (CSST)." All commercially available CSST systems are certified to the list of requirements included in this standard.

In addition to the first of its kind piping system standard, there is another unique element found in the use of CSST. In an effort to prevent widely different hardware products and installation practices from entering the marketplace, the Gas Research Institute (GRI) offered the results of its gas industry sponsored research to potential manufacturers at no cost. By sharing its intellectual property, GRI was able to also standardize many of the common aspects of the CSST system. In fact, the following is a list of common practices found among U.S. manufacturers of CSST systems:

- Tubing size designations
- System sizing methods
- General installation practices
- Protective shield design
- Protection requirements
- Bonding requirements

All CSST manufacturers are required to publish a Design and Installation (D&I) Guide, and per the ANSI LC-1 Standard, the content of this guide must follow a prescribed format. Included within this format is the requirement to address electrical bonding and grounding. Furthermore, because of years of industry cooperation, essentially all of the design and installation guidelines are identical between all six manufacturers. This is a critical point affecting the bonding of CSST systems and will be discussed later in this report

1.3 Lightning Impact

Lightning is one of the most destructive forces of nature. Direct and indirect strikes on or near structures can cause severe damage to the building and initiate fires that can result in the loss of property and lives. Despite this destructive power and with a few exceptions, jurisdictions throughout the United States do not require the installation of lightning protection systems. Instead, the electrical grounding system is required to address (as best it can) the issue of mitigating the lightning energy. However, the

electrical grounding system is only designed to protect the building occupants from ground-faults and not from lightning strikes. It should, therefore, be no surprise that many metallic systems (such as wiring, coax cable, piping, and ducting) either fail or are damaged during electrical storms.

Lightning strikes can be direct and/or indirect. The effects from a direct strike on a structure are from resistive heating, arcing, and burning. A direct strike typically results in catastrophic damage to the structure and its contents, and is considered by most experts to be “beyond the means of man to prevent”. The National Electrical Code (NEC) specifically considers lightning protection “beyond the scope” of the Code. While installing a lightning protection system will afford a certain level of protection from direct strikes, the system is primarily designed to protect the structure and not necessarily the interior electrical and plumbing systems.

The effects from an indirect strike near a structure include capacitive, inductive, and magnetic behavior. The lightning current can branch off to a building from a nearby tree, fence, light pole, or other tall object. In addition, a lightning flash may conduct its current through the ground into a building. The current also may travel through underground power cable, telephone lines, or metallic piping. The protection of both structures and people from the dangerous effects of an indirect lightning strike requires that both the structure and all metallic systems within the structure be bonded together so as to act as a single unit. To accomplish this goal, the following steps are required:

- Grounding of the electrical system to the earth
- Bonding of all grounding electrodes together (including those associated with a lightning protection system if installed)
- Bonding of all metallic structures to this grounding system

When properly sized and installed, bonding can minimize the electrical potential difference between these parallel metallic pathways to ground. This will significantly reduce the occurrence of any physical damage to any of the affected systems when they are energized by a lightning strike.

1.4 Grounding and Bonding Considerations

Effective grounding depends on a low-resistance electrical pathway connected to the earth. The pathway to ground is affected by the resistance within the voltage system, the grounding electrode(s) and the soil conditions. The electrical resistance of the pathway to ground must be 25 ohms or less per the NEC. If not, an additional grounding electrode must be installed. Section 250.4 (A) (1) of the 2005 National Electrical Code states the following:

“Electrical System Grounding: *Electrical systems that are grounded shall be connected to earth in a manner that will limit the voltage imposed by lightning, line surges, or unintentional contact with higher-voltage lines and that will stabilize the voltage to earth during normal operation.”*

The surge of energy throughout the premise wiring and the other metallic systems during a lightning event can be hundreds of times greater than the normal current running through the house. These lightning surges are also occurring at much higher frequencies than normal electrical voltage. The combination of lightning current and frequency create conditions that are difficult to mitigate if the grounding and bonding systems are inadequately sized. The critical design issue involves the capability of each and every parallel metallic pathway to be energized to the same level and have that energy rise and fall at the same speed as the lightning strike completes its cycle. This capability creates an equal potential state between these pathways to ground and limits (if not eliminates) any differences in electric potential between these pathways.

Damage caused by a lightning strike to a CSST system can be described as small puncture of the tubing wall as shown in Figure 1. This type of damage is caused by an arc of energy “jumping” from a pathway of higher potential to a pathway of lower potential in an effort to find a lower impedance pathway to ground. This type of damage has been reported by forensic investigators [ref 1] and appears to be consistent around the country. By balancing the electric potential between these possible pathways, the conditions necessary for arcing can be eliminated. **Therefore, the sizing and installation location of the bonding jumper between the gas piping system and the grounding electrode system becomes the critical elements in an effective lightning mitigation method.**

The remainder of this report addresses the issue of bonding of gas piping systems to the electrical system grounding electrode system and how to achieve a balance between code requirements, manufacturer’s instructions, and the need to protect the public safety.



Figure 1 Typical Lightning Damage to CSST

2.0 Codes and Standards

2.1 Model Codes:

2.1.1 National Electrical Code

The National Electrical Code (also known as NFPA 70) is essentially used throughout the United States, typically with a few amendments to account for local building practices, climate conditions or other geotechnical concerns (such as earthquakes or floods). The current edition was published in 2005, but the 2008 edition is expected to be available by the end of 2007. Unless specifically noted, all references made to the NEC used in this report are based on the 2005 edition.

As mentioned earlier, the NEC does not include direct coverage for the installation of or performance requirements for a lightning protection system. There are, however, national standards for the installation of lightning protection systems (discussed later in this section) which are referenced within the Code. Section 250.106 does address the bonding of a lightning protection system (if installed) to the grounding electrode system, and refers the reader to NFPA 780-2004 as the relevant standard. However, there are other standards for the installation of lightning protection systems including:

- LPI-175/2004 Standard of Practice for the Design, Installation and Inspection of Lightning Protection Systems

- UL-96A Installation Requirements for Lightning Protection Systems

The NEC does provide extensive (over 25 pages) coverage on the subject of grounding and bonding in Section 250 of the Code. As stated previously, grounding is the intentional connection of a current carrying conductor to ground (earth). There are three basic reasons for grounding:

- To limit voltages caused by lightning or by accidental contact of the supply conductors with conductors of higher voltage
- To stabilize the voltage under normal operating conditions
- To facilitate the operation of over-current devices (such as fuses, circuit breakers or relays) under ground-fault conditions

Bonding is the permanent joining of metallic parts to form an electrically conductive path that ensures electrical continuity and the capacity to safely conduct any current likely to be imposed. The purpose of bonding is to establish an effective path for fault current that, in turn, facilitates the operation of the over-current protection device.

To simplify the Code, only the electrical system (consisting of the premises wiring) is grounded for residential applications. The electrical system is grounded to earth through grounding electrodes typically a rod, pipe or plate. However, there are other means to ground the electrical system including the use of the reinforcing steel in the foundation. All other electrically continuous, metallic pathways (such as water pipe (if copper), coax cable and gas piping) are bonded to this grounding system. Bonding of gas piping, in particular, is installed in accordance with Section 250.104 (B):

(B) Other Metal Piping. *Where installed in or attached to a building or structure, metal piping system(s), including gas piping, that is likely to become energized shall be bonded to the service equipment enclosure, the grounded conductor at the service, the grounding electrode conductor where of sufficient size, or to one or more grounding electrodes used. The bonding jumper(s) shall be sized in accordance with 250.122, using the rating of the circuit that is likely to energize the piping system(s). The equipment grounding conductor for the circuit that is likely to energize the piping shall be permitted to serve as the bonding means. The points of attachment of the bonding jumper(s) shall be accessible.*

FPN: Bonding all piping and metal air ducts within the premises will provide additional safety.

Referring to Section 250.122 (Size of Equipment Grounding Conductors), Table 250.122 provides guidance for sizing the bonding jumper for the gas piping system:

(A) General. *Copper, aluminum, or copper-clad aluminum equipment grounding conductors of the wire type shall not be smaller than shown in Table 250.122 but shall not be required to be larger than the circuit conductors supplying the equipment.*

Table 250.122: Minimum Size Equipment Grounding Conductors for Grounding Raceways and Equipment:

15 AMP	=>	14 AWG Copper
20 AMP	=>	12 AWG Copper
30/40/60 AMP	=>	10 AWG Copper
100 AMP	=>	8 AWG Copper
200 AMP	=>	6 AWG Copper

Therein lies the problem. The NEC sizes the bonding jumper based on the circuit that is likely to energize the gas piping system. Traditionally, this is the circuit that powers the appliance to which the gas piping is mechanically connected. The equipment grounding conductor (the third wire) is permitted to act as the means of bonding of the gas piping back to the grounding electrode system. For a typical electrical load up to 20 amperes, as long as the third wire is a 12 AWG copper wire, the bonding requirement of the Code is met. While this will protect the consumer from ground-faults and other wiring failures, a 12 AWG copper wire is inadequate to protect the appliance and gas piping from an indirect lightning strike where the voltage and frequency can be significantly higher. It is important to note that the NEC does not require any bonding of a gas piping system that is only connected to non-powered appliances such as a water heater or fireplace log.

The coverage for bonding of gas piping in the electrical code has varied over the past few code cycles as special interests have successfully made their arguments for modifications within the NEC. As shown in Table 1, bonding has alternated between direct bonding and the use of the equipment grounding conductor over a six-year period from 1996 to 2002. This is a significant change in practice and affects both the size and location of the bonding jumper depending on how this requirement is interpreted by the local electrical inspector.

2.1.2 National Fuel Gas Code

The National Fuel Gas Code (NFGC) or NFPA 54 is the primary code document in the United States that covers the design, installation and inspection of natural gas and LP gas systems for all types of applications including residential, commercial and industrial. For the purposes of this report, the Code has had coverage for electrical bonding and grounding going back to the 1988 edition which is the year that CSST was commercially introduced in the United States. In the intervening 20 years, the coverage for bonding has only been changed once. The coverage for bonding in the 1988 edition was as follows:

(a) Each above ground portion of a gas piping system upstream from the equipment shutoff valve shall be electrically continuous and bonded to any grounding electrode as defined in the National Electrical Code, ANSI/NFPA 70.

(b) Gas piping shall not be used as a grounding electrode.

This language remained in effect for the 1992, 1996, and 1999 editions. In the 2002 edition the language was modified as follows:

(a) Each above ground portion of a gas piping system that is likely to become energized shall be electrically continuous and bonded to an effective ground-fault current path. Gas piping shall be considered to be bonded when it is connected to gas utilization equipment that is connected to the equipment grounding conductor for the circuit supplying that equipment.

(b) Gas piping shall not be used as a grounding conductor or electrode.

This is essentially the same language found in the 2006 edition although the term equipment has been replaced with the term “appliance”. Table 1 shows how bonding coverage (for gas piping) has varied between the NFGC and the NEC since the 1996 editions of these codes. The change made in 2002 to the bonding requirements has a significant impact on the sizing and installation of the bonding connection with the electrical system.

The NFGC is the lead code regarding the coverage for bonding of gas piping systems and its recommendations are sent to the appropriate NEC committees for consideration. Given the high impact of this issue, several proposals have been submitted to the NFGC to update the coverage for bonding of gas piping. Although proposals were submitted to require direct bonding of all gas piping materials, the Technical Committee discussed and accepted a modified proposal that limits the direct bonding of gas piping systems to CSST alone. The proposed language, which was accepted and is out for public review and comment, is as follows:

Table 1 Bonding Requirements: Model Codes and by CSST Manufacturer

Code Coverage	1992	1996	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
NFGC: Bond to Electrode	X	X	X										
NFGC: Bond to EGC						X			X				X
NFGC CSST-6 AWG Proposal													X
NEC: Bond to EGC		X				X			X			X	
NEC: Bond to Electrode			X										
Ward: bond requirements						NEC66				NEC66	NEC66		
Gastite: bond requirements		NONE						EGC		NEC66	CSST6		
TracPipe: bond requirements			NONE					NFG99	NEC66		NEC66		
Parker: bond requirements				NFG99						NFG99	NEC66		
TruFlex: bond requirements							NFG99			NFG99	NEC66		
MetalFab: bond requirements							NONE		NONE		NEC66		

Legend:

- **EGC:** Equipment grounding conductor (see Section 2.1.1)
- **NFG99:** 1999 edition of the National Fuel Gas Code (see Section 2.1.2)
- **CSST6:** Bonding of CSST per the latest Technical Bulletins: 6 AWG copper wire
- **NEC66:** D&I/Technical Bulletin for bonding CSST in accordance with NEC Table 250.66

7.13.1 Each aboveground portion of a gas piping system that is likely to become energized shall be electrically continuous and bonded to an effective ground-fault current path. Gas piping shall be considered to be bonded when it is connected to appliances that are connected to the appliance grounding conductor of the circuit supplying that appliance.

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.

7.13.2 Gas piping shall not be used as a grounding conductor or electrode.

Add the following two new definitions:

Bonding Jumper: A reliable conductor to ensure the required electrical conductivity between metal parts required to be electrically connected. [NFPA 70]

Grounding Electrode: A device that establishes an electrical connection to the earth.

If the proposed change to the NFGC on CSST bonding is approved, there will be a significant difference between the 2009 NFGC and the 2008 NEC that will have to be addressed by the NEC committees when they consider changes for the 2011 edition.

2.2 State and Local Codes

Within the United States, the individual states choose to adopt any of the available model national codes for the construction of residential and commercial buildings including electrical, plumbing, mechanical, energy, etc. Although there are 50 state governments that promulgate state-level codes and standards, there are over 14,000 local jurisdictions that, in some cases, have similar authority to choose which codes to enforce within their boundaries. Fortunately, the process of choosing and enforcing codes and standards at the state and local level has been streamlined in the last decade, and now there is more similarity than difference at the state/local levels. In fact, there are essentially only three pertinent national model code organizations that are currently affecting this issue. These organizations and the pertinent codes are as follows:

- International Code Council (IFGC and IRC)
- International Association of Plumbing and mechanical Officials (UPC)
- National Fire Protection Association (NEC and NFGC)

All 50 states used the NEC (NFPA 70) as a baseline document with some state level amendments. Approximately 35 states use the International Fuel Gas Code with some state amendments. The remaining states use either the Uniform Plumbing Code or the NFGC also with state amendments. The adoption of model codes varies from state to state. The impact of the code in effect within any state is influenced by which edition is

currently adopted, and whether the state has approved any local amendments that reflect special local practices or weather conditions.

The implementation of new bonding requirements will be affected by the adoption process used by the states. Model codes are not immediately adopted upon publishing, and, therefore, new coverage in the model code is not immediately effective at either the state or local level. Assuming that the new coverage for CSST bonding is adopted by the NFGC in the 2009 edition, it may take until sometime in 2010 or later before these new requirements are adopted and enforced at the state and local levels. Most states have formal processes for the review and adoption of model codes. Therefore, immediate national and local acceptance of the new bonding requirements is impossible to achieve. This creates a significant time delay prior to local enforcement. This requires that each state be individually approached and requested to adopt these requirements on an interim basis on a much shorter time schedule. This process has been started, but it is laborious and difficult because of the reluctance of state officials to act independently from the model code organizations.

2.3 Product Standards

2.3.1 ANSI LC-1 Standard for CSST Systems

The ANSI LC-1 Standard includes a group of technical requirements that, taken as a whole, represents a level of safety and performance deemed reasonable for a gas piping product. The standard does require that the manufacturer supply a set of design and installation instructions which must be written to a prescribed format. The format dictates that the design and installation manual must include a section on electrical bonding and grounding including a statement about not using the CSST as a grounding electrode for an electrical system. A recent proposal to the standard (out for public review and comment) would modify this requirement to “*provide information to address the permanent electrical bonding of the CSST system*”. However, the specific instructions are left to each manufacturer to develop.

The standard does not currently include any tests for electrical properties such as continuity and conductivity. However, if included, these tests would only be performed for energy levels up to fault currents from the premise wiring system and not for lightning. This issue has been discussed at recent LC-1 Working Group meetings, and new proposals for additional electrical testing are expected to be submitted during 2007. It is expected that these tests will be similar to those used to test electrical conduit. The standard also does not include any tests that involve resistance to lightning currents or the dissipation of lightning energy. Although considered by the Working Group, these types of tests are clearly beyond the scope of this type of product standard. None of the existing gas product standards include any requirements for lightning protection. Development of a set of reasonable testing requirements and acceptance criteria would be extremely difficult to accomplish given the extremely wide range of lightning characteristics.

2.3.2 NFPA 780 Standard for the Installation of Lightning Protection Systems

As previously mentioned, there are at least three standards covering the installation of lightning protection systems. Lightning protection systems are not required by the National Electric Code, but have been adopted by a few states including Florida where lightning is a proven and consistently occurring problem. Lightning protection systems are installed separately from the premise wiring systems, but are required to be bonded together with the electrode grounding system of the premise electrical system in accordance with NEC Section 250.106. It is important to note that lightning protection systems are designed to protect the structure and not the electrical and plumbing systems contained within the premises. Also, lightning protection is only provided for direct lightning strikes, and does little, if anything, to protect the structure, electrical and plumbing systems from indirect lightning strikes.

3.0 Manufacturer's Instructions

3.1 General Comparison of D&I Guides

As required by the ANSI LC-1 Standard, each CSST manufacturer must provide a design and installation (D&I) manual or guide. The content in these manuals are primarily based on the original CSST research sponsored by GRI in the 1980s. This is apparent by reviewing the six different D&I guides and noting that many paragraphs and drawings are identical for all of the manufacturers. This is also true for the coverage for electrical bonding and grounding. Historically, the requirements for bonding were drawn directly from the model codes. This was not a concern for the CSST manufacturers because the model codes assign the responsibility of bonding to the electrical contractor who typically works independently from the CSST installer. CSST systems were in compliance with the NEC and NFGC without any additional work on the part of the CSST installer or manufacturer because the bonding was accomplished through the equipment grounding conductor or was not installed at all. Therefore, until 2004, the requirement for bonding was identical within all CSST manufacturer's D&I Guides.

3.2 Comparison of Bonding Requirements

Although CSST has been sold in the United States since 1988, not all of the current manufacturers have been in business the same length of time. In fact, the original commercial supplier of CSST went out of business within two years of starting its operation. The D&I Guide is occasionally updated to reflect additions to the product line, changes in code requirements, and actions related to the ANSI Standard. Therefore, the total number of D&I Guides ever published and their latest versions has varied greatly over the past 20 or so years. Table 1 summarizes the bonding requirements in the D&I Guides for each manufacturer for their recent editions going as far back as 1996 for some. Suffice it to say, that as of June 2007, there are six different CSST D&I Guides and all have been recently updated according the following list:

- Wardflex: Design and Installation Guide: March 2007
- Parflex: Design and Installation Guide: September 2006
- Gastite: Design and Installation Guide: January 2007
- TracPipe: Design Guide and Installation Instructions: March 2007
- Pro-Flex: Installation/Training Guide: August 2006
- Diamondback: Design Guide and Installation Instruction Manual: August 2005

Given the expense of reprinting and distributing these D&I Guides, not all changes are included within the guides as they become available. Rather than reprint, each manufacturer typically issues periodic technical bulletins that alert their installers, distributors and members of the enforcement community about modifications to their hardware or changes to installation instructions or new sizing tables. Manufacturers also announce changes to their requirements on their individual websites. This is the case regarding the new bonding requirements for CSST. However, whenever these D&I Guides are reprinted, these technical bulletins are incorporated. Four of the six CSST manufacturers have issued technical bulletins regarding the new bonding requirements for CSST. One manufacturer has already updated their D&I guide and one manufacturer has only issued a general announcement on the subject.

Although only four of the six CSST manufacturers were parties to the Class Action suit, all six have informally agreed to upgrade their bonding requirements for the CSST system. Generally speaking, the new bonding method requires the attachment of a bonding clamp to either the CSST fitting or to a piece of steel pipe located near the service entrance to the building. The bonding jumper shall be no smaller than a 6 AWG copper wire (for residential applications). Although the final bonding solution is essentially the same for all six manufacturers, the six technical pronouncements appear to be quite different.

The 6 AWG copper bonding wire solution can be developed through different interpretations of the electrical code. One approach uses the water piping as a direct comparison in terms of sizing of the bonding jumper. In another case, the size of the bonding jumper is based on the size of the bonding jumper used for a lightning protection system. If NEC Table 250.122 is used, then the selection of a 200-Amp service results in a bonding jumper of size 6 for copper wire. There are other similar bonding jumper sizing approaches used for communications cable and other metallic systems that also lead to the use of a 6 AWG copper jumper.

What is problematic is the requirement to size the bonding jumper in accordance with Table 250.66. This table is intended for sizing of the grounding electrode conductor (not the same as the bonding jumper) which is based on the size of the ungrounded service conductor at the entrance of the building. This can result in a bonding jumper much larger than a 6 AWG copper wire especially for large buildings and/or multi-family structures. Using the exception in Section 250.66(A), if a rod, plate, or pipe is used as the grounding electrode, the grounding electrode conductor need not be larger than a 6 AWG copper wire. The argument still must be made (to the local electrical inspector) that the bonding jumper be sized in a similar fashion. However, this exception is open

to interpretation and can be misused when sizing the bonding jumper. Therefore, caution is recommended when referring to this particular section of the NEC.

Until these six sets of installation instructions are written with identical language, there will be confusion in the field (both installers and inspectors) and the real possibility of improperly sizing the bonding jumper. Efforts are underway to remedy this situation.

3.3 Conflicts with Code Requirements

As discussed previously, the speed of technology change far outruns the speed of institutional change. Updating of the model codes simply cannot keep up with the pace of new product introductions and changes to installation practices. Therefore, the model codes have accepted the need to depend upon the manufacturer's installation instructions to supplement the code coverage especially where new equipment is concerned. Section 110.3(B) of the NEC and Section 1.1.2 of the NFGC recognize that listed equipment shall be installed in accordance with the code requirements and the manufacturer's instructions. If conflict arises between the code and these instructions, the code usually requires the more restrictive requirement to prevail but not always. If there is a perceived danger in following the manufacturer's instructions, the authority having jurisdiction (local inspector) can overrule the manufacturer's instructions or just reject the installation of a particular product or system until the matter is resolved at a higher level.

The acceptance of the CSST manufacturer's bonding instructions has met with a mixed review around the United States. While some states defer entirely to the manufacturer's instructions, other states have fully rejected the direct bonding requirements until they complete their own due diligence study. Therefore, adoption of these new installation practices must not only pass through a model code hoop, they must also pass muster with local electrical and mechanical inspectors and building officials.

3.4 CounterStrike Product

While all CSST products are similar in concept, there are variations in the shape and thickness of the convolutions and the fitting construction and assembly. None of these differences, however, significantly affects how the CSST responds to lightning energy and how lightning damages the tubing after a strike. However, one manufacturer (Omegaflex) has developed a CSST product called CounterStrike™ that is specifically designed to dissipate the energy from an arc from another energized metallic system. The thin, standard yellow coating has been replaced with a thicker proprietary (black) jacket material designed to dissipate energy along its length. Omegaflex claims that the CounterStrike™ product inhibits lightning energy from concentrating at any point along the gas line and spreads out the energy over a larger area. This feature minimizes the possibility of a breach of the tubing wall when the CSST is struck by an arc. However, CounterStrike™ must also be bonded to the same specifications that are required for the standard TracPipe CSST product. Therefore, the additional protection from the jacket and its effectiveness compared to other similarly bonded CSST products has not

been independently confirmed. More robust bonding may, in fact, be all that is minimally required to be effective.

4.0 Conclusions

The set of unfortunate circumstances that has led the CSST industry to require direct bonding of their gas piping systems is well documented. The damage caused by indirect lightning strikes to these CSST systems is based on differences in electrical potential between parallel metallic pathways to ground which results in an arc between two imbalanced paths. The damage is not a result of the some deficiency of the CSST to carry the lightning current. Therefore, the developed solution to the problem is based on eliminating the imbalance in electrical potential rather than any direct physical change to the CSST itself. These potential imbalances are well known to the electrical industry and the tried and proven solution is equi-potential bonding of all metallic pathways inside the building. To achieve equal potential, these parallel systems must be bonded to the electrical grounding system through a conductor attached directly between the metal (of the system) and the grounding electrode system (in accordance with the NEC).

CSST manufacturers have always required that CSST systems be bonded to the electrical system in accordance with the NFGC and the NEC. However, the bonding methods prescribed within these documents are minimum requirements and are designed to protect the consumer against ground-faults from the premise wiring system. Neither code requires protection against lightning strikes. The proposed bonding method includes the use of a 6 AWG copper wire attached to the gas piping system at the service entrance and connected to the grounding electrode system in accordance with the NEC. All six CSST manufacturers have agreed to implement this requirement on all future installation whether or not the gas equipment that is connected is electrically powered or not. Although the bonding instructions of the six CSST manufacturers currently appear to be different, they all result in the same final installation. Efforts are underway to develop a universal set of installation instructions that will be adopted by all CSST manufacturers.

Parallel efforts are proceeding to update the model fuel gas codes and electrical codes at a national level. However, this process will take years to accomplish. The NFGC is considering a change for the 2009 edition, while the earliest change to the NEC would occur in the 2011 edition. While progress is being achieved on modifying the national codes, efforts are also being made to modify state and local codes on a much faster schedule. State and local jurisdictions are being approached on an individual basis to adopt the manufacturer installation instructions immediately or within a few months time. In addition, the governing product standard is also undergoing a review and update process.

5.0 Reference Materials

5.1 Technical Publications

[ref 1] Goodson, Mark, Lightning Induced CSST Fires, Interscience Communications Limited, Fire and Materials 2005 Conference, San Francisco, February 2005.

5.2 Websites

Ward Manufacturing
115 Gulick Street
Blossburg, PA 16912
<http://www.wardmfg.com/>

Omegaflex
260 North Elm Street
Westfield, MA 01085
<http://www.tracpipe.com/>

Gastite
603 Hendee Street
Springfield, MA 01139
<http://www.gastite.com/>

Parker Hannifin Corporation
Parflex Division
1300 North Freedom Street
Ravenna, OH 44266
<http://www.parker.com/parflexsystem/>

Tru-Flex Metal Hose
PO Box 85
Howell, MI 48844
<http://www.tru-flex.com/>

Metal-Fab Inc.
3025 May Avenue
Wichita, KS 67201
<http://www.mtlfab.com/>