Validation of Installation Methods for CSST Gas Piping to Mitigate Lightning Related Damage

Phase 1

Final Report

Prepared by:

SEFTIM

THE FIRE PROTECTION RESEARCH FOUNDATION

FIRE RESEARCH

THE FIRE PROTECTION RESEARCH FOUNDATION
ONE BATTERYMARCH PARK
QUINCY, MASSACHUSETTS, U.S.A. 02169
E-MAIL: Foundation@NFPA.org
WEB: www.nfpa.org/Foundation

FOREWORD

Installation requirements in NFPA 54, the National Fuel Gas Code, and various manufacturers' instructions address recommended bonding for CSST gas piping. However, a number of fires have been reported resulting from gas leaks from punctures in CSST Piping due to lightning events. The goal of this Phase I study was to carry out a literature review and gap analysis to inform a future research project designed to validate installation methods for CSST gas piping to mitigate damage due to lighting events.

The content, opinions and conclusions contained in this report are solely those of the authors.

Validation of Installation Methods for CSST Gas Piping to Mitigate Lightning Related Damage

Phase 1

Project Technical Panel

Denise Beach, NFPA staff liaison
Mitchell Guthrie, Consulting Engineer
John Hall, NFPA
Richard Hoffmann, Hoffmann & Feige
Michael Johnston, National Electrical Contractors Association
Ted Lemoff, TLemoff Engineering
William Rison, New Mexico Institute of Technology
John Tobias, U.S. Department of the Army
Robert Vondrasek, NFPA

Prinicipal Sponsor Representatives
Remington Brown, Institute for Business and Home Safety
Michael Daniel, Tru-Flex Metal Hose Corp.
Tibor Egervary, Ward Manufacturing
Mark Harris, Titeflex Corp.
Mark Morgan, Lightning Safety Alliance
Bob Torbin, Omega Flex, Inc.

Contributing Sponsor
Shaun Ray, Metal-Fab, Inc.

Project Contractor
Alain Rousseau, SEFTIM

SEFTIM	**49, RUE DE LA BIENFAISANCE - 94300 VINCENNES** SA. AU CAPITAL DE 152 449 € – RCS CRETEIL B 316 719 855 SIRET 316 719 855 00025 – CODE APE 742 C CERTIFIÉE ISO 9001

THE FIRE PROTECTION RESEARCH FOUNDATION

Final report for Validation of Installation Methods for CSST Gas Piping to Mitigate Lightning Related Damage

April 2011

Executive Summary

This document provides the final report for the Fire Protection Research Foundation Phase 1 effort on the validation of installation methods for corrugated stainless steel tubing (CSST) gas piping to mitigate lightning-related damage. It includes:

- a literature review
- consultations with experts
- a gap analysis

The lightning experts (mainly international experts), who were not involved in the CSST case studies, believe that the observed holes on CSST, based on pictures we provided, may not be caused by induced surges but by direct lightning currents or by partial lightning currents. Power fault current is also considered as a possible cause for such holes.

For some experts directly involved in the CSST case studies, it is also considered that power faults could be a primary cause for the damages. However, at least a few examples have been provided where it can be shown that electrical lines were not involved. If surges were coming from the power network, it would be easier to explain the damages since the induced surges are probably stronger, but a few cases of damages occurred far away from the power conductors or when power had already been lost in the structure.

It is likely that there is not a single mode of damage.

The study then concentrates on indirect lightning (partial lightning current) and induced lightning. Direct lightning is also addressed even if, in the case of direct strike to the structure, the presence of a lightning protection system as required by NFPA 780 needs to be considered. As a matter of fact, if protection against direct lightning is not considered for a specific building, we cannot expect CSST to survive such an

event.

Induced lightning is represented by a weaker impulse (8/20 µs wave) compared to *direct lightning* (10/350 µs). The duration of induced lightning is short in comparison to the duration of a direct lightning strike. *Partial direct lightning* (part of a direct lightning current, with smaller magnitude but the same waveshape as direct lightning current, sometimes called indirect lightning) has the same duration but a smaller magnitude as a direct strike.

Induced lightning can create damaging surges. These surges are created by a *source* (a lightning current creating a magnetic field that is stronger if nearer) and a *receptor* (the loop between a long overhead power line and the earth, for example). Induced surges are also created on underground lines, but they are weaker and mainly dependent on the soil resistivity.

In the US, gas is supplied to a facility from tanks adjacent to the facility, from buried or aboveground tanks in the vicinity of the facility connected by buried metallic piping, or by buried municipal service using either metallic or plastic (polyethylene) piping to the service entry. In all these circumstances the induced surges are probably weak. However, the surges may create (especially when the supply piping is made of copper or black pipe with no bonding at the service entrance of the installation) a sparkover between CSST exposed to an induced voltage and another metallic grounded part.

Holes also occur when the supply pipe is short (as when the tank is in the vicinity of the house). In those cases it appears that the voltage is induced onto the runs of CSST instead of propagating from the gas supply pipe.

Additional studies and tests (including simulations) will help understanding the magnitude of such induced surges and whether they could be damaging.

For induced surges the energy may be induced on the power circuit or on the CSST circuit itself. Some mitigations that have been presented as solutions are: appropriate bonding of the CSST, establishing a separation distance between CSST and other metallic circuits (such as chimneys or power lines), use of CSST with enhanced lightning-withstanding capabilities, or even a combined solution. Such requirements appear in the latest installation rules for some manufacturers. However, based on some studied CSST cases, holes do not always occur where the distance between the CSST and a metallic part is the smallest, and thus separation distance may be difficult to address.

The efficiency of bonding for high frequency has been discussed. Lightning is a high frequency event and it is known that for direct strikes at 1 MHz, a 1-meter length of copper may lead to a voltage drop of 1 kV or more. Not only does the ground to which the CSST is bonded need to be of low impedance (and probably lower than the other circuits including the gas tank itself) but also the length of the bond needs to be short. In some of the cases we have studied, the only bonding was in the attic at the manifold (which means that the bond was probably quite long) with bends at angles of less than 90 degrees, which is probably not sufficient at high frequencies.

It is interesting to note that CSST damage due to lightning is most prevalent in the USA. Many countries supplied no feedback but they are using either short lengths of CSST (UK) or their use of CSST is quite recent (France). In some cases CSST is used in only one application (e.g. South Korea). It is interesting to note that Japan, which is apparently the prime developer of CSST, is also recording a few damages, and some warnings appear in installation documents regarding bonding and proximity to metallic parts. However, the only country for which a list of damages can be easily found on the internet or in magazines is the USA. This may be due to a larger use of CSST or, as explained by one of the manufacturers, less stringent rules for equipotential bonding in the US in conjunction with a greater use of nonmetallic conductors in houses (plastic pipe used instead of metal pipes, wifi instead of cables and so on) with CSST remaining one of the few metallic skeletons of a house, which therefore stresses the CSST more than in the past.

To determine if the bonding solution as defined in NFPA 54 is adequate, possible threat scenarios have been defined. It would have been nice to have enough field experience to determine if any of these scenarios can be eliminated from consideration. However, most of them have been validated by at least one documented case. Once again, the quantity of documented incidents for which we have detailed data is far too small to derive any pertinent statistics or even trends.

In comparing the scenarios with tests published so far, we see that some tests or simulations are missing. The needed tests and simulations are described in the text. With four types of tests, all scenarios can be covered. Testing means are not described in detail when they use generic generators and configurations typical of lightning tests. These tests need to be performed with current generators (not combination wave generators) producing the required waveshapes, described in the test description (i.e. 10/350 or 8/20). For each proposed test, the purpose of the test is described. For tests that are not typical to the lightning industry, a test layout is also described.

To cover the full picture, all four types of tests need to be performed. A minimum test program is suggested, depending on what needs to be covered:

The text concludes by answering the initial questions raised at the origin of the study:

- Bonding of CSST is probably not the only solution in the case of direct lightning strikes, but protection based on NFPA 780 should be provided for those cases.
- For induced and indirect lightning, bonding at the entrance of the installation will help reduce the stress, but a global equipotential solution

is necessary to achieve a complete solution. Multiple bonding would also help.

- Separation distance is another solution that could be explored as part of an overall package, but it may not be sufficient by itself.
- Alternatively, CSST specifically designed to withstand an enhanced lightning surge may be considered, provided their behavior is supported by tests.
- Bonding should be done with a short length of conductor with minimum bends, regardless of the source of lightning threat. Acceptable bonding length can be determined through tests supplemented with computer simulations.
- Bonding with #6 AWG needs to be validated by more tests since the tests published so far do not cover the complete picture, even though #6 AWG is the normal size for equipotential bonding conductors and should be enough.

It is also suggested that CSST be specifically included in the NFIRS form in order to have tools in future to validate that the provided solutions have been appropriate.

Contents:

1. FOREWORD

This document provides the final report for the Fire Protection Research Foundation Phase 1 effort on the validation of installation methods for corrugated stainless steel tubing (CSST) gas piping to mitigate lightning-related damage. This document fulfills the last deliverable of the Fire Protection Research Foundation Contract. It includes:

- a literature review
- consultations with experts
- a gap analysis

2. STATEMENT OF LIMITATIONS

This document should not be used or interpreted outside of its context. In particular, partial copy of the report may lead to false interpretations. The limited number of incidents reported doesn't allow us to draw general conclusions. To cover this issue, warnings have been introduced in many places in the text.

Normally, consultation of experts is conducted after a literature review. It appears that in fact these two actions should to be started simultaneously, as they are more connected than it appeared to us initially. In fact, experts contacted at the preliminary stage provided us with a lot of additional data and literature which was beneficial to the literature review.

However, the literature review was not as easy as expected.
In spite of an additional month provided to finalize it, we are missing data especially from insurances companies or from field experience of experts involved in cases studies. Furthermore, some manufacturers didn't send contributions.

Most of the experts contacted either had no additional data regarding CSST or were under confidential agreement for their studies. Some of them were expecting to release published reports by the end of 2010 or beginning of 2011, but most of them were clearly unauthorized to send any data in spite of apparently in-depth knowledge of the topic. In fact, only one expert did show us detailed data of his studies, though in a draft form, and did spent quite a long time discussing the matter with us. At the time of the final report, we didn't receive the expected report.

Insurances companies are unable to provide data until they solve all the litigation cases they have.

Three manufacturers have provided us with quite interesting data. One of them has proposed a visit of its plant for a better understanding of the manufacturing process and to answer any questions we may have.
Others didn’t reply.
Data on CSST sales for all US manufacturers have been compiled by AHRI.

Other people contacted such as lawyers have been unable to send any data until their cases are resolved in court. One lawyer was expecting to be able to release data one month after the court decision, but this has not been possible

This means that the literature review has some limitations.

The list of the persons and the companies we have contacted in the USA is given in Annex 1.

In the following sections, the name of the files we used is written as a number in italics and in brackets, followed by the file name highlighted in yellow (for example, [*xxx*: *name_of_file.ppt*]). All relevant materials have been received in an electronic format and are therefore associated with a file name. A table in Annex 2 gives, along with the name of each file, title, author’s name and date of the paper in which it is contained. The table also provides additional clues to help the reader to access the paper.
The quotes from these papers are given in quotation marks highlighted in blue (“ “). A quote may not be the exact author’s quote, but rather a simple summary which makes the reading

easier in the context of this report.

The extracts of papers which are quoted hereunder or their summaries are stated in good faith.

No document provided to us under a confidential agreement has been included in this report.

Authors of statements copied in this report that helped in summarizing or commenting on an issue are not mentioned specifically, except when otherwise specified. These authors' statements are given in quotation marks highlighted in grey ("   ") and have a note format with smaller font than the main part of the text. For a better readability these authors' statements are only given in quotation marks highlighted in grey ("   ") in Annexes. Those statements are related to either oral or written private communication and so no document is available for review by the reader of this report. It must be noted that no one requested we not mention their name.

3. INTRODUCTION

The data collected regarding fires due to lightning in combination with CSST are either too broad in scope or too limited in quantity to derive definitive conclusions. However, preliminary conclusions are given in Chapter 6, as they have been the basis for the gap analysis and proposed test/simulations for part II of the project.

Data collected by NFIRS are not generally specific with relation to the involvement of CSST and have generally few narrative details associated. It would be useful to know if CSST was involved, if the CSST was bonded, and if so bonded to what, what the quality of bonding and grounding was, and so on. This is the type of detail we expect from case study reports of lightning experts, but these reports are not produced by lightning experts; as previously stated, most of them have been unable to provide such required information to us.

Examples of narrative parts from NFIRS reports involving CSST (from OHIO) are given below.

DISPATCHED TO HOUSE FILLING WITH SMOKE AFTER LIGHTNING STRIKE. ON ARRIVAL FOUND SMOKE COMING FROM CHIMNEY AND OTHER AREAS. OCCUPANTS WERE ALREADY OUT. ON ENTRY FOUND BASEMENT FILLED WITH SMOKE AND NO VISIBILITY. PUT ATTACK LINE IN PLACE AND VENTED BASEMENT WINDOWS. FOUND FIRE CONFINED TO SPACE BETWEEN TWO FLOOR JOISTS IN BASEMENT CEILING. SHUT OFF GAS WHEN GAS SMELL WAS DETECTED. ON OVERHAUL FOUND SOME KNOB AND TUBE TYPE WIRING WHICH HAD POSSIBLY SHORTED OUT ON DUCT WORK. FOUND TWO CIRCUIT BREAKERS TRIPPED. ALSO FOUND SMALL PINHOLE BURNT IN FLEXIBLE GAS LINE USED TO SUPPLY GAS FIREPLACE. THIS WAS RIGHT WHERE THE FIRE DAMAGE WAS GREATEST. MOVED OCCUPANTS BELONGINGS OUT OF AREA AND REMOVED SOME DUCT WORK TO GAIN BETTER ACCESS FOR OVERHAUL. RETURNED TO SCENE AT 0630 TO CHECK FOR REKINDLE.

RESPONDED ON REPORTED STRUCTURE FIRE. CREWS CAME FROM HOME DUE TO OVERLOAD OF CALLS. LT. RICE ASSUMED COMMAND AND L-361 CREW ASSISTED WITH EXTINGUISHMENT AND OVERHAUL WITH OTHER COMPANIES.MAIN AREA OF ORIGIN WAS THE BASEMENT AREA AND EXTENDED THROUGH THE FIRST FLOOR. TWO CATS WERE LOST IN THIS FIRE WITH NO OTHER INJURIES REPORTED. CAUSE UNDER INVESTIGATION BY PV-361. Investigation; THE CAUSE OF THE FIRE WAS A LIGHTENING STRIKE THAT CAUSED GROUNDING OF THE COORAGATED STAINLESS STEEL TUBING (CSST) LOW PRESSURE GAS LINE WHICH BLEW A PINHOLE AND IGNITED THE GAS CAUSING BURNING OF THE FLOOR STRUCTUE. jbg 5-24-2004

noted address called and stated he thought his house was struck by lightning, and that his wife woke and smelled smoke. When Mr. Lauferweiler checked the basement he found a moderate amount of smoke. As he went further into the basement he saw flames coming from a plastic wrapped flexible gas line that runs under the first floor. He immediately shut off gas line and fire was extinguished. He wanted an engine to come out and check out the house. E210's crew checked all rooms, attic with thermal camera and found no smoke or hot spots. The gas line that ruptured fed a gas log fire place, where it ruptured and caught fire ran directly beneath a large steel I beam support. The flames spread upward and charred the 2 x 8 floor joist directly above it. Charring was minimal. Heat from fire also created a small pin hole leak in a pvc water line running just below gas line. Shut off water valve to that line. Steel beam was slightly over 200 degrees per thermal camera upon our arrival. Was reading at just over 100 degrees when unit left the scene. Home owners security system and phones were also knock out. No electrical breakers were popped in main electrical panel. Crew found no visible entry points where lightning strike hit. Poss struck the chimney cap, ran down the metal chimney liner to the gas line. Advised homeowner to contact insurance co. and alarm co. Capt. Olson

Examples of Narrative Parts from NFIRS Reports

Application of bonding of CSST is also difficult to discern. If the date of bonding in NFPA 54 is clearly documented (2009 edition), it appears that this has been proposed to NFPA by manufacturers who had already implemented such bonding requirements in their own applications. First date of application of bonding in the field, then, is unclear.

Some of the damages that have been reported to us happened before bonding was required. So we cannot really derive relevant conclusions from these installations where bonding was not required by code.

Note:

In addition, "more than 14,000 national, state and local codes exist in the USA. In some occurrences, those codes are not cross-code consistent. The ways they are enforced through inspection and inspectors sometimes increase the level of inconsistency: the inspector may bring his own interpretation of the code wording and of which code is to prevail. This may create difficulties to assess how CSST is installed and bonded in each place."

Note:

A lightning expert added, "There is truth to this and it is causing a lot of problems in the lightning protection industry. The only way to solve the problem is to resolve the solution to what to do with CSST and then aggressively educate the AHJs (Authorities Having Jurisdiction) at all levels so we can get consistency. Right now they (AHJs) are being told different things by different groups and this propagates the confusion."

It is stated in [*149: CSST Gas Line Bonding - BCW.ppt*]: "CSST installations and proper bonding lack uniformity:

- Good municipal inspectors assure proper installations.
- Other municipalities don't even know of the issue.
- They rely on the plumbers (who don't know about grounding).
- They rely on the electricians (who aren't looking at the plumbing)."

Of course a few cases of incidents where CSST was supposed to be bonded according to NFPA 54 had been reported when the change to the *NEC* was proposed. This is apparently one of the reasons why the present study was launched. However, when details were requested regarding these cases, the following answer was obtained: "The Standards Council task force did discuss CSST incidents, but no specifics were provided."

Note:

However, one of the experts noted that "most of the cases reviewed had some level of bonding of the CSST, although it was not clear what relevant specification has been used (i.e. manufacturer specification or NFPA standard)." The data provided to support this statement are not in a written format, so it is difficult to really draw a conclusion regarding bonding relevance.

However, the list of incidents given in Annex 3 will show that in some cases damages have been reported in spite of bonding.

Some of the few documented case studies we have received so far seem to show that bonding was present in a few occasions where damage was reported.

But it is clear that to be useful, a reported and documented case needs to provide at least the following details:

- Is there a Lightning Protection System?
- Is there a direct strike on the building itself?
- Is there a bonding to the CSST? Where is the CSST bonded and to what?
- What is the quality of the bonding?
- What is the quality of the grounding; especially at high frequency?

These details were quite often missing.

Regarding the possible sources of energy that may have caused the damages to CSST, an informal discussion occurred with many lightning experts during the International Conference on Lightning Protection (ICLP) in September, 2010. It appears that most lightning experts believe there is not enough energy in induced lightning to create a hole in CSST, even if an arc is created by the lightning-induced voltage between CSST and another element.

According to those experts, the main cause of damage could be an arc between CSST and another element through which a significant current from direct lightning or from electrical fault circulates. Considering the current of lightning, it is likely to be a long duration current, even if it is of low magnitude

3.1. Direct strikes to a structure

According to the experts involved in the provided case studies and incident reports, only a very small number of CSST damages due to direct lightning have been reported on buildings protected by Lightning Protection Systems (LPS).

A few cases occurred with direct lightning on buildings not protected by LPS, but in those cases we cannot derive any conclusions since a direct strike to a building should be dealt with by an LPS whether or not there is CSST inside the structure. We will study this configuration in the report, as this may lead to some specific requirement when direct lightning is expected.

3.2. Electrical faults

The arc (flashover) between the CSST and the electrical circuitry may be caused by a lightning surge. A fault current can then flow to the CSST and supply the arc for quite a long time before an overcurrent device opens the circuit.

3.3. Induced surges

Although it is not the most probable cause of damage according to the contacted ICLP experts, we need to study the induced surge.
Regarding induced lightning strikes, the amount of energy depends on the size of the induction loop. Experience with utilities has shown that significant surges can be experienced on overhead power lines, due to the large loops which exist between the overhead conductors and the ground.
In the case of CSST, new installations are now partly supplied by insulated pipe (Polyethylene, or PE) and no longer by black iron pipes. Due to galvanic corrosion issues, there is a trend toward using plastic piping for municipal supply. Therefore, there is no overvoltage generated on the plastic pipes.
For steel pipes, the pipes run underground, which limits the voltage generated in the loop. The overvoltages are then related to the soil resistivity and no longer to loop dimension: the coupling between the steel pipe and the lightning current will be greater where the soil resistivity is larger.

In some of the documented cases we have been able to study, the gas is supplied from an underground tank in the vicinity of the house and not through a pipe coming from a municipal network. The length of pipe between the tank and the house is then limited, so the induced surge should be very low.

Note: As can be seen in Annex 3, rural areas have more buried tanks; cities and suburban areas typically have distributed networks.

3.4. Indirect strikes

An indirect strike is a strike close to a structure or house, generating a partial lightning current in the metal links of the building (such as gas pipe or electrical grounding) through soil coupling. For buried tanks, this is the most likely scenario to explain damages, since induced surges can certainly be disregarded due to small length of buried pipe. This partial direct current (which is quite powerful) is able to generate a hole in CSST when an arc is created between CSST and an alternate path to ground (path of lowest impedance).

3.5. Direct strikes to one of the services supplying the house

An alternative scenario is a surge generated on the power line (which is more likely to occur than a surge on the telecom line, considering the size of the conductors), not mitigated by the meter spark gap, with a potential rise between the electrical conductors and the grounded CSST. An electrical earth fault current then circulates in the arc, which could lead to a hole in the CSST if the lack of steel thickness is not able to mitigate the stress created at the arc root (this is where the stress is biggest in an arc). This direct strike scenario can involve lightning strikes from farther away, compared to the indirect strike scenario

A few case studies show that the CSST was punctured far away from electrical lines or even any apparent metal part.

Note:

One expert declared “I am aware of installations that have had melt-through and not been in the proximity of AC wiring and only near other metal conductors within the building such as metal air ducts or other metal systems in a wood construction house.” This tends to show that electrical faults alone are not enough to explain all the observed damages.

The influence of the electrical conductors and metal parts in the vicinity of CSST, as well as the possible involvement of the CSST characteristics in the process, need to be thoroughly studied. It is necessary to try to explain all the documented case studies before being able to draw a final conclusion. For example, in some cases, many punctures were observed on one or two CSST runs. Normally, if there is an arc between the CSST and a metal part, this arc should drop the voltage between CSST and metal part to a level where another arc (and thus another hole) cannot be generated.

4. USA LITERATURE REVIEW AND CONSULTATIONS WITH EXPERTS

4.1. Development of a risk context for CSST gas piping damage incidents through a statistical review of CSST incidents (both leaks and fire incidents) in all types of structures, including insurance company records; overall lightning damage related incidents; and fire incidents, with a geographic perspective

4.1.1. INCIDENT STATISTICS PROVIDED BY VARIOUS SOURCES

CSST consists of a continuous, flexible stainless steel pipe with an exterior PVC or Polyethylene covering (PE).

The history of CSST coverage in the USA started in 1983 from a research and development project sponsored by the Gas Research Institute. The initial standards were developed by the American Gas Association Laboratories and were designated in 1987 as *AGA 1-87*. This standard became an ANSI standard in 1991. In 1989, the *National Fuel Gas Code* introduced coverage of CSST.

In 2004, a class action suit was filed and settled in 2006, resulting in the addition of requirements for bonding and, eventually, installation of lightning protection. The resultant code/standard changes only addressed bonding: In 2009, the *National Fuel Gas Code* introduced coverage of bonding the CSST.

In Annex 3, a short list of documented incidents is presented (they have been documented up to a certain extent; see the statement of limitations in the Introduction).

The initial purpose of the list was to obtain statistically valid CSST incident distribution from across the country, based on detailed studies and validated by more global sources as NFPA reports (based on NFIRS) or by insurance statistics. Failure to obtain a large number of detailed cases prevented us from getting this complete list. We got data from 4 sources.

Note: Leaks have not been addressed specifically, due to a poor incident database. Most of the incidents reported to us are related to fire more than to leakages. Only a few cases in Annex 3 describe leaks without fire. It is interesting to note that, as can be seen from the foreign literature review, some countries are more concerned with CSST termination than with CSST itself.

4.1.1.1. First source: NFPA

In terms of incident statistics, there are a few available studies from NFPA. These studies are based on NFIRS (National Fire Incident Reporting System).

Note:

In addition, we got the following values from one manufacturer:

"In the USA there are 22 million lightning strikes per year; 4,800 fires related to lightning; 2,100 fires related to natural gas; 22,000 fires related to electrical wires and equipment; 250 fires related to lightning and wires; 80 or 90 fires involving lightning and gas equipment before the introduction of CSST; and 140 fires involving lightning and gas equipment after the introduction of CSST."

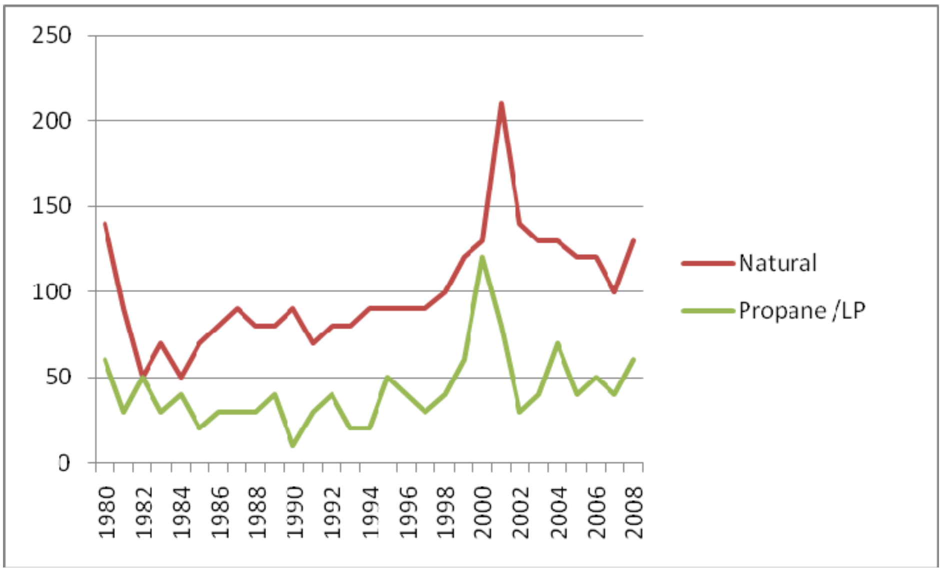
Results of one of the NFPA studies are given in [*3*: *1543- Home Structure Fires in Which Natural Gas or LP-Gas Was Ignited by Lightning.pdf*].

This document is based on reports from fire departments and state fire authorities from the NFIRS (National Fire Incident Reporting System). This reporting system doesn't include details regarding CSST, except when some narrative is included. However, narrative parts, if any, are not reported in this document, which only provides a statistical overview.

The following note is included in the document:

"Note: These are national estimates of fires reported to U.S. municipal fire departments and so exclude fires reported only to Federal or state agencies or industrial fire brigades. These national estimates are projections based on the detailed information collected in Version 5.0 of NFIRS. NFIRS 5.0, first introduced in 1999, instituted major changes in the coding rules and definitions. Estimates for 1999-2008 are based on NFIRS Version 5.0 data only. These tables include a proportional share of fires in which the type of material first ignited and heat source was unknown or not reported. Because of low participation in NFIRS 5.0 during 1999-2001, estimates for those years are highly uncertain and must be used with caution. Fires are rounded to the nearest ten."

Results of this study can be summarized in the following figure. It presents the 1980–2008 annual estimates, by year, of home structure fires in which natural gas or LP gas was ignited by lightning (excluding confined fires).



Home Structure Fires in Which Natural Gas or LP Gas Was Ignited by Lightning, by Year, 1980-2008

There is a peak in year 2000 but, as indicated in the note copied above, it may not be significant. The statistics provided stop in 2008, before the new version of NFPA 54, with its requirements for mandatory bonding of CSST, was implemented.

The average value per year is 100 for natural gas and 42 for LP gas.

One noticeable aspect is that there are more incidents involving natural gas (supplied through a longer utility network) than incidents involving LP gas (supplied through a nearer tank). But this may not be relevant either, since new installations of natural gas generally include plastic (PE) tubing on the utility side, and the longer utility piping network doesn't make any difference in terms of induced lightning if it is not made of metal. This trend may be related to increased use of natural gas or to any other cause independent of the supply characteristics. Especially, there is no evidence that CSST was used in these cases. Furthermore, assuming CSST was used, there is no clue to determine whether the CSST was bonded.

> Note: Gas distribution from the community network to consumers is mainly in PE (polyethylene) for new installations. It was made of metal in the past.

A new NFPA report has been produced recently, by the same authors, titled [*4 : 1553 - home lightning gas by region, area, and item.pdf*].

This report gives various statistics, one of them being the breakdown of home structure fires caused by lightning in which natural gas or LP gas was the type of material first ignited, by US census regions, between 2004 and 2008.

For natural gas, 122 cases are reported, in comparison with 55 cases for LP gas. When those numbers are compared to values from the previous study (respectively 600 and 260), the ratio between LP gas and natural gas incidents remains almost the same (30% for LP gas and 70% for natural gas) but the number of events decreases a lot. The last statistic is probably closer to what we are looking for even if the CSST part in these cases is not established. It is also nearer to what one manufacturer declared in terms of observed incidents, as stated above.

Details of the study are given below:

Natural gas:

U.S. Census Region	Fires	
Northeast	11	(19%)
South	23	(43%)
Midwest	19	(35%)
West	1	(2%)
Total	55	(100%)

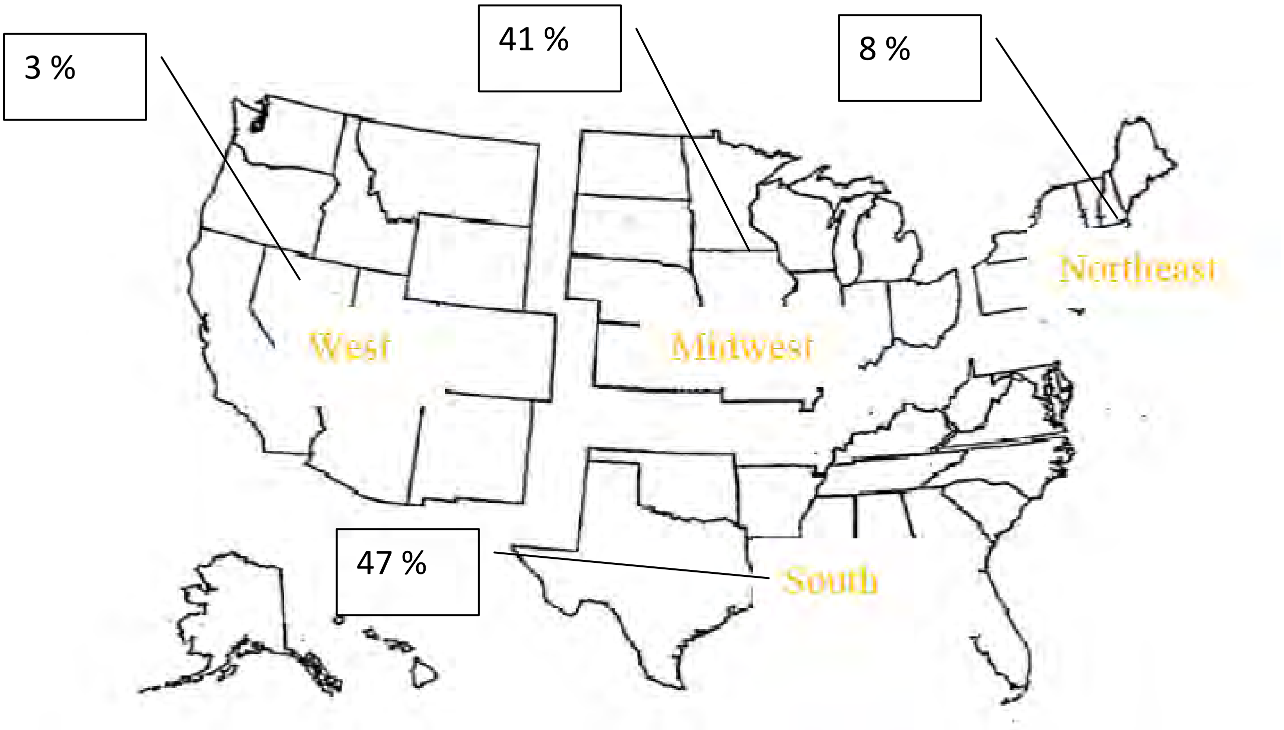
Home Structure Fires in Which Natural Gas Was Ignited by Lightning, by Year, 1980-2008

LP gas:

U.S. Census Region	Fires	
Northeast	4	(3%)
South	61	(50%)
Midwest	53	(43%)
West	4	(3%)
Total	122	(100%)

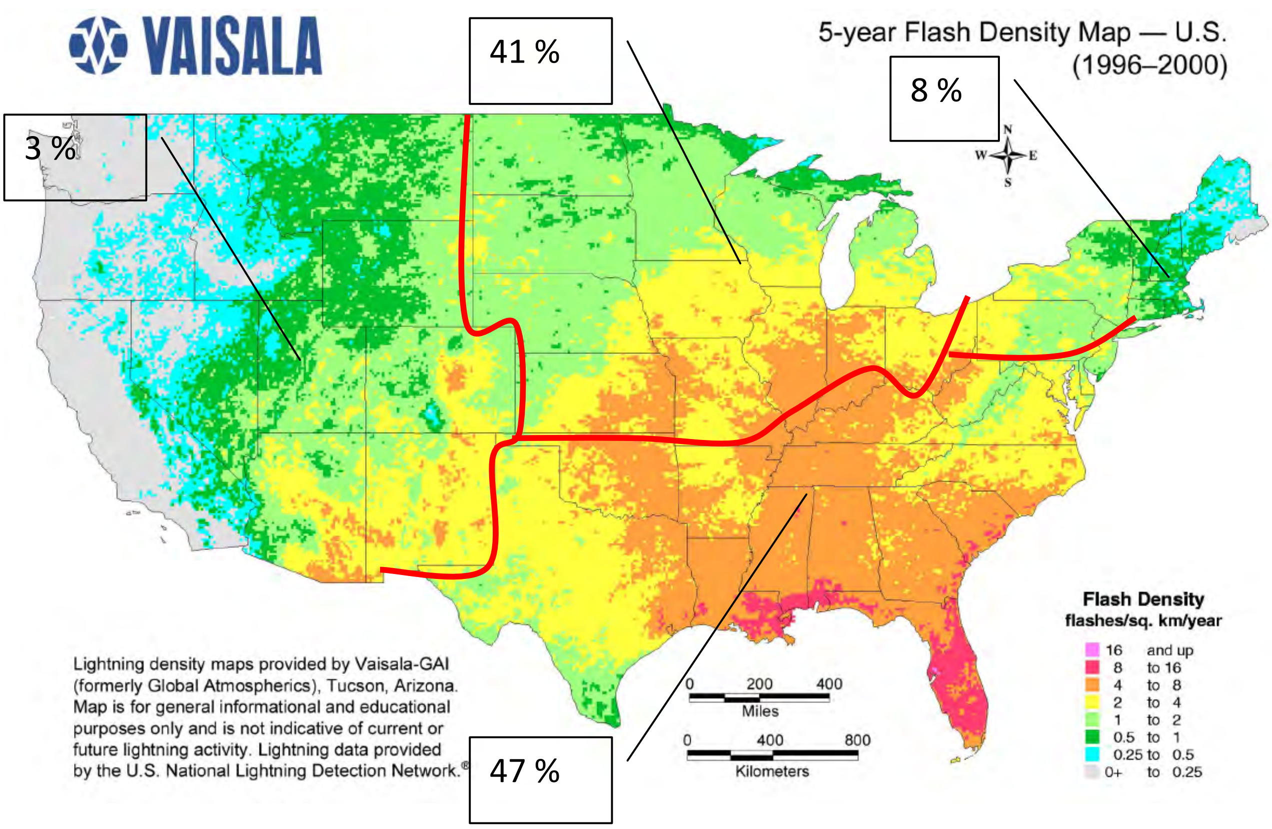
Home Structure Fires in Which LP Gas Was Ignited by Lightning, by Year, 1980-2008

This can be presented on the following map:



Home Structure Fires Caused by Lightning, by US Census Regions

The lightning flash density map of USA where data from the previous report are reported is provided below for comparison.



Flash Density Map with Fire Statistics

If we try comparing those data it appears that they don't match very well, except in the South where there are more incidents and more lightning strikes. To be relevant, this comparison should be done in such a way that it allows comparison of lightning flash density not only to percentage of incidents but also with km of CSST installed (per year, if possible). Statistics are too broad in terms of geographic spread to be really helpful in the current study and also the statistics are not defined accurately enough due to the fact that CSST is not coded in NFIRS.

As a preliminary conclusion, there is not an immediate conclusive link between lightning flash density and lightning fires for which gas is the first material ignited.

It should be noted that the most likely places for fire to start as given by the same NFPA document [*4*: *1553 - Home Lightning Gas by Region, Area and Item.pdf*]. (17%) are in attic or ceiling/roof assembly or concealed space that is code 74 of NFIRS coding.

> Note: 'According to the 2004 NFPA Glossary of Terms, a *concealed space* is defined as "That portion of a building behind walls, over suspended ceilings, in pipe chases, attics, and in whose size might normally range from 44.45 mm (1 in.) stud spaces to 2.44 m (8 ft.) interstitial truss spaces that might contain combustible materials such as building structural members, thermal and/or electrical insulation, and ducting." This definition is from NFPA 96, *Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations,* 2008 Edition and applies only to NFPA 96.'

Most of the fires listed have flammable or combustible liquid or gas in or escaping from containers or pipes as the item first ignited (62%), excluding engines, burners and their fuel systems.

> Note:
> Another expert provided us with some statistics:
> "There are over 120,000,000 residential housing units (single and multi-family) in the United States. The predominant construction method used in the residential market consists of wooden framing members and wooden sheathing and a concrete foundation. Because homes are made from very combustible materials, it should come as no surprise to learn that there were over 377,000 residential fires last year (2009) in the United States. Approximately 22,000 annual fires were directly attributable to a failure of the electrical distribution system or lighting equipment. During that same period (2003-2007), there were approximately 2,100 annual residential fires attributable to a failure of some component of the fuel gas distribution system (for all reasons including lightning) within the premise."

4.1.1.2. *Second source: published reports*

Data on reported incidents can also be found in [*125*: *p.379 Goodson Gasline and Lightning .pdf*].

Authors indicate that:

"Frisco (Texas) Fire Department sought to ban CSST

Fire Department Arlington, Texas was aware of 4 fires in their jurisdiction where lightning caused CSST.

Report issued by Donan Engineering: multiple fires were described that involved lightning and CSST located in the Midwestern United States."

In addition, when contacted, one of the authors of this publication declared that he had studied 100 cases.

Another source declares having seen around 57 cases. These cases seem to be well documented, but the author cannot release this information at this time.

Another source gives interesting details: [*149*: *CSST Gas Line Bonding - BCW.ppt*]
According to a recent Angie's List article (http://magazine.angieslist.com/story/special-report_flexible-gas-lines-bear-inspection):

- Fishers, Indiana (suburb of Indianapolis – population 65,000) had 33 house fires this year (as of 10/15/2008)
- 10 involved lightning strikes
- 3 of those involved CSST (2 more suspected)

Preliminary conclusions: there are not enough details in the published report to draw conclusions about the number of CSST incidents

4.1.1.3. Third source: LSA database

The LSA database is also an interesting input for our study. A partial copy is included below. It is a database of incidents in which people have chosen to report their lightning-related incidents. All the cases are not related to CSST and it is interesting to note that most of the cases are related to direct strikes.

Preliminary conclusions: there are not enough CSST incidents listed to draw conclusions.

Previous data have not helped so much to understand the CSST situation, as they were not directly related to CSST.

Date Received	Structure State	Structure Type	Construction Type	Electric	Natural Gas	Other	Type of lightning strike	Fire Damage	Electronic Damage	Wiring Damage	Other Damage	Brief Description	Comment relevant to our study
01/10/2010	FL	Commerical	Metal Frame	yes	no		indirect	no	yes	no	no	damage to electronic equipment hardwired between buildings in a campus environment	not relevant to our study
01/05/2010	OH	Single Family	Wood Frame	no	no		indirect	no	no	yes	no	Strike to utility pole near house	not relevant to our study
21/01/2010	TX	Residential	Wood Frame	no	no	Propane CSST	Direct	yes	no	no	no	none provided	
17/11/2009	KY	Commerical	Permanently Moored Vessel	no	yes	Black iron piping	direct	yes	no	yes	no	High intensity arc patterns on decked	Direct strike problem
30/10/2009	TX	Residential	Wood Frame	yes	yes	Corrugated stainles steel tubing	Direct	yes	yes	yes	no	caused house fire	Direct strike problem
16/10/2009	WI	Residential	Wood Frame	no	no	Propane	indirect	yes	no	yes	no	Struck propane tank, then ignited the house	CCST not mentionned
16/10/2009	DE	Residential	Wood Frame	no	yes	Black iron piping	Direct	no	yes	yes	yes	Melted wires,struck gutter of house	Direct strike problem
13/10/2009	WI	Multiple Family	Wood Frame	yes	yes	Corrugated stainles steel tubing	Direct	yes	yes	yes	no	casued damage to structure	Direct strike problem
12/10/2009	WI	Single Family	Wood Frame	no	yes	Black iron piping	unknown	no	yes	yes	no	electronical devices were damaged	not relevant to our study
09/10/2009	NC	Single Family	Wood Frame	yes	no		indirect	no	yes	yes	no	Fried everything	not relevant to our study
09/10/2009	MI	Residential	Wood Frame	no	yes	Black iron piping	indirect	no	yes	no	no	Destroy circuit boards on furnece	not relevant to our study
06/10/2009	FL	Residential	undefined	yes	yes	Corrugated stainles steel tubing	unknown	yes	yes	yes	yes	Roof damage, then spread	Probably a direct strike

Extract from LSA Database

4.1.1.4. Fourth source: incidents directly related to CSST compiled from two sources

We also received statistics from other sources more dedicated to CSST. All together they include 141 cases.

It is interesting to note that among these 141 listed incidents only 15% are related to bonded CSST, 36% of the events are related to direct lightning strike, and only 5 (4%) are cases where the incident occurred in spite of CSST bonding for which direct lightning was not involved. It seems clear from the literature review that the bonding of CSST, as required by NFPA 54, was not intended to provide complete protection in case of direct lightning strike, thus damage in spite of bonding seems quite explainable.

> Note:
> For example, one of the experts having proposed and justified CSST bonding declared "It should also be understood that in the absence of a properly installed lightning protection system, a direct lightning strike to the structure is beyond the ability of any man-made system and/or equipment to absolutely protect the building and its contents from severe damage."

In addition, reference [71] indicates: A testing protocol was developed … to model an indirect lightning flash striking near the house and the associated energy entering the premise (and the gas piping system) through a pathway provided by the electrical service entrance.

For three of these five cases, the installation was either indirectly bonded or bonded but not at the entrance of the installation. However, for two of these five cases, there is no explanation regarding the quality of bonding, to allow us going further in the analysis.

18% of the cases only mention damages related to electrical lines, but many other cases mention the presence of other metal parts at the very place where the arc did connect. It is important to notice that one explanation given by some experts regarding possible cause of CSST damages is the power follow current coming from the mains. The 18% of the cases only tend to show that other causes may exist. In addition, damage to electrical equipment at the same time that CSST is damaged doesn't mean that the CSST and equipment occur at the same place in the house and are connected together. A lightning strike may cause simultaneously CSST damage and electrical equipment damage at two different locations inside a house.

The results of the 141 combined cases are listed in the table below.

Reported	Date of Potential Lightning-Related Incident	State	Type of Strike (Direct or Indirect)	Bonded/ Grounded	Arc to	Chimney	Location	Path of Electricity	Date Installed or Date of Construction
1	7/17/96	IN	Unknown.	Unknown.	No hole	Unknown.	Unknown.	Unknown. significant other damage included failures in	Unknown.
2	7/18/96	IN	Unknown.	Unknown.	Unknown.	Unknown.	Attic.	Unknown. No fire reported. Leak only	Unknown.
3	7/19/96	IN	Direct	Unknown.	Unknown.	Unknown.	Crawl space.	Unknown; gas line to Fireplace affected. No fire reported; leak only.	Unknown.
4	8/23/02	IN	Unknown.	No bonding or grounding.	Unknown.	Unknown.	Unknown.	Unknown.	Spring 1999.
5	1/13/03	KS	Indirect	Ground rod; bonding unknown.	Concrete wall (hole was within ½ inch of wall).	Unknown.	Basement.	Unknown.	Late 2002/early 2003.
6	05/10/2003	IN	Direct.	No bonding.	Unknown.	Unknown.	Unknown.	Fireplace gas line affected.	01/03-05/03
7	07/03/2003	TX	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	2000
8	08/01/2003	IN	Unknown.	No bonding.	Unknown.	Unknown.	Joist spaces between basement and first floor.	Unknown.	Unknown.
9	5/21/04	OH	Direct.	No bonding or grounding.	Metal heating duct.	Metal chimney cap.	basement ceiling	Direct strike to chimney cap.	Between 9/02 and 11/02.

Reported	Date of Potential Lightning-Related Incident	State	Type of Strike (Direct or Indirect)	Bonded/ Grounded	Arc to	Chimney	Location	Path of Electricity	Date Installed or Date of Construction
10	5/21/04	OH	Direct.	Grounded; indirectly bonded.	HVAC duct	Metal chimney chase and flue vent.	Between basement and first floor.	Direct to the chimney cap; fireplace line affected.	Between 2001 and 2002.
11	5/30/04	IN	Indirect.	No bonding or grounding.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
12	06/12/2004	OH	Direct.	Grounded; indirectly bonded.	Copper water line or metal HVAC duct.	One chimney chase with metal vent cap.	Basement.	Direct to the chimney cap; fireplace line affected.	2001
13	6/16/04	IN	Direct	Unknown.	metal floor beam, which was in contact with CSST	Metal chimney cap.	basement	Chimney cap, through chimney liner to fireplace gas line.	Built in late 1999.
14	6/16/04	IN	Indirect.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Built in late 1999.
15	08/11/2004	CT	Unknown.	No bonding or grounding.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown; home was in process of being constructed.
16	3/21/05	TX	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Around 11/03.
17	4/22/05	IN	Direct.	No evidence of bonding or grounding.	Unknown.	Unknown.	Attic.	Direct hit to chimney; fireplace gas line affected.	Home built in 2003
18	7/16/05	IN	Direct.	No bonding.	Unknown.	Unknown.	Basement.	Fireplace gas line affected.	Home built in 1996.
19	8/13/05	IN	Direct.	Indirect bonding.	HVAC duct	Two steel chimneys.	Basement.	Through chimney.	Home built in 2002.

Reported	Date of Potential Lightning-Related Incident	State	Type of Strike (Direct or Indirect)	Bonded/ Grounded	Arc to	Chimney	Location	Path of Electricity	Date Installed or Date of Construction
20	08-May	IL	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
21	08- May	FL	Direct.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
22	08- May	FL	Direct.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
23	4/14/06	IN	Direct.	No bonding.	Unknown.	Two chimney caps.	Basement.	Lightning struck house 8- 9 ft. off ground directly above HVAC unit and in vicinity of two gas lines; fireplace line affected.	Home built in 2004.
24	4/14/06	IN	Direct.	Grounded; bonding unknown.	Romex wire; copper water line.	Metal chimney cap.	1st floor hallway ceiling.	Lightning struck metal chimney cap and entered house through metal flue system and steel fireplace box.	Home built around 1999.
25	5/18/06	IN	Direct.	No bonding; there were grounds running from the pipes on the water heater to the outside.	Unknown.	Two steel vents.	Attic.	Fireplace line affected.	Home built in 1994.
26	06/12/2006	SC	Unknown.	Unknown.	Unknown.	Unknown.	Crawl space.	Unknown.	Unknown.
27	9/17/06	MN	Indirect.	Grounded, but not	HVAC duct;	Unknown.	Basement.	Unknown.	Late 2002/early

Reported	Date of Potential Lightning-Related Incident	State	Type of Strike (Direct or Indirect)	Bonded/ Grounded	Arc to	Chimney	Location	Path of Electricity	Date Installed or Date of Construction
				bonded.	arcing occurred where CSST was in direct contact with HVAC duct.				2003.
28	10/04/2006	IN	Unknown.	Bonded at water heater.	Ventilation duct or nearby Romex wires.	One metal chimney cap.	Basement.	Main CSST line affected.	Home built in 2002.
29	03/01/2007	MO	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
30	03/01/2007	OH	Unknown.	Unknown.	Steel support beam.	Unknown.	basement	Unknown.	Approximately 2005.
31	06/12/2007	VA	Indirect.	Not grounded; bonding unknown.	Unknown.	Unknown.	Crawl space between basement and first floor.	Strike to ground near house.	Unknown.
32	08/09/2007	OH	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
33	08/09/2007	IN	Unknown.	Grounded and indirectly bonded.	Copper water line.	Unknown.	Basement	Unknown.	2004
34	8/16/07	IN	Direct.	Direct bonding.	Metal HVAC duct that was likely touching the CSST.	One chimney cap.	Basement.	Direct strike to chimney cap through metal chimney flue to fireplace gas line.	House built in 2002.
35	1/24/08	PA	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
36	03/02/2008	WI	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
37	3/27/08	IN	Direct.	Not bonded or	Copper water pipe,	Stainless steel	Basement	Through direct strike to	03/05i

Reported	Date of Potential Lightning-Related Incident	State	Type of Strike (Direct or Indirect)	Bonded/ Grounded	Arc to	Chimney	Location	Path of Electricity	Date Installed or Date of Construction
				grounded	which was in direct contact with CSST.	chimney cap showed three areas of pitting from direct strike.	crawlspace.	chimney cap through to fireplace line.	
38	05/07/2008	IN	Unknown.	No bonding; single ground rod.	Electric service branches, thermostat control wiring, ductwork.	Brick chimney chase.	1st floor kitchen and basement.	Unknown.	Unknown.
39	5/30/08	IN	Direct	No bonding; electrical service not properly grounded.	Unknown.	Metal chimney flue.	Basement.	Energized chimney flue; fireplace gas line affected.	1999
40	06/04/2008	IN	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Installed more than ten years prior to suit.
41	06/04/2008	IN	Unknown.	Not bonded or grounded.	Copper water line, which was in direct contact with CSST.	Stainless steel cap and double-walled stainless steel vent pipe with cap.	Basement.	Unknown; main gas line affected.	2000
42	06/05/2008	MD	Direct.	Not bonded and connections to grounding rods were	Unknown.	Metal chimney vent.	Room above garage, 2nd floor.	Through furnace vent pipe and/or strike to house itself.	2004-2005

Reported	Date of Potential Lightning-Related Incident	State	Type of Strike (Direct or Indirect)	Bonded/ Grounded	Arc to	Chimney	Location	Path of Electricity	Date Installed or Date of Construction
				loose as were the rods themselves.					
43	06/09/2008	IN	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	2006
44	6/19/08	MO	Unknown.	Unknown.	Unknown.	Unknown.	Under sub-flooring.	Fire marshal concluded that lightning struck ground and traveled through copper water lines into house.	1997
45	6/25/08	OH	Direct.	Indirect bonding.	Unknown.	Unknown.	Unknown.	Unknown.	05/06-11/06
46	07/12/2008	IN	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	2005
47	07/12/2008	AR	Unknown. Family stated that they believed lightning struck house.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Mid-April 2006 (house not complete until March 2007).
48	7/22/08	OH	Indirect.	Indirect bonding.	metal ductwork	Unknown.	Basement.	Unknown.	2006 (homeowner installed himself).
49	08/05/2008	IN	Direct.	Manifold was grounded but firebox was not.	Electrical wiring, which was in	Wooden chimney chase with a stainless steel cap	Basement	Direct strike to chimney cap; current moved down through chimney	2005

Reported	Date of Potential Lightning-Related Incident	State	Type of Strike (Direct or Indirect)	Bonded/ Grounded	Arc to	Chimney	Location	Path of Electricity	Date Installed or Date of Construction
					direct contact with the CSST.	and two ground-mounted satellite dishes; metal chimney cap showed signs of several strikes.		liner to firebox and then into the CSST.	
50	8/5 – 08/06/2008	IN	Direct.	Manifold directly bonded to copper wire pipes and then to the electrical supply panel.	Steel beam.	Metal chimney.	Unknown.	Direct strike to metal chimney; fireplace gas line affected.	2005-2006
51	8/16/08	CO	Direct.	Unknown.	Unknown.	Chimney cap was blown off.	Unknown.	Direct strike to chimney cap.	Unknown; home occupied by 2004.
52	8/30/08	OK	Direct.	Unknown.	Unknown.	Metal vent cap.	Unknown.	Direct strike to roof and chimney cap.	Unknown.
53	10/22/08	OK	Direct.	Unknown.	N/A	N/A	N/A	Direct strike to roof.	Unknown.
54	02/09/2009	MT	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
55	4/14/09	NJ	Unknown.	Unknown.	Unknown.	Unknown.	Fire began in gas-fired heater. House stripped to studs before	Unknown.	Unknown.

Reported	Date of Potential Lightning-Related Incident	State	Type of Strike (Direct or Indirect)	Bonded/ Grounded	Arc to	Chimney	Location	Path of Electricity	Date Installed or Date of Construction
							inspection took place.		
56	4/17/09	TX	Indirect	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
57	05/07/2009	GA	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	2006
58	05/12/2009	CT	indirect	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	2007
59	06/08/2009	IN	Direct.	Unknown.	Unknown.	Framed chimney chase with galvanized chimney cap; cap showed signs of lightning contact at several points.	basement	Direct strike to chimney cap.	2000-2001
60	06/11/2009	KS	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
61	07/11/2009	IN	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	2005
62	07/12/2009	NY	Direct.	No bonding.	Unknown.	Metal chimney flue.	Unknown.	Strike to nearby tree and jump to flue; current traveled through to fireplace gas line.	August 2006
63	7/23/09	MN	Indirect.	Unknown.	Edge of house.	Unknown.	basement	Strike to birch tree, traveled through ground, to guide wire, into house.	July 2008
64	08/04/2009	IN	Unknown.	Unknown.	HVAC	Unknown.	Unknown.	Unknown.	Unknown.

Reported	Date of Potential Lightning-Related Incident	State	Type of Strike (Direct or Indirect)	Bonded/ Grounded	Arc to	Chimney	Location	Path of Electricity	Date Installed or Date of Construction
65	08/04/2009	IN	Direct	No bonding or grounding.	Metallic ductwork and/or steel beam (CSST ran parallel to and was touching both).	Evidence of direct strike to metal chimney cap.	Basement and first floor.	Through chimney cap; fireplace and main gas lines affected.	4/24/2002
66	08/08/2009	MN	Direct.	Unknown.	One CSST line to another.	Unknown.	basement	Unknown.	Early 2007.
67	10/01/2009	WY	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
68	12/06/2009	KY	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
69	1/20/10	AK	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	2008
70	4/28/10	MI	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
71	5/31/10	OH	Direct.	Directly bonded.	Unknown.	Unknown.	basement	Unknown.	2008
72	06/04/2010	NC	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
73	06/04/2010	NC	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
74	6/19/10	MI	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	2004
75	6/27/10	IN	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
76	07/11/2010	AR	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	2006
77	07/12/2010	IN	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
78	7/21/10	NY	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
79	08/02/2010	FL	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
80	08/04/2010	VA	Unknown. whether lightning struck in area at time of	Not directly bonded.	N/A	Metal chimney cap used to vent hot water heater, but no evidence of direct strike at	1st floor	Unknown; water and gas lines to house are PVC.	2008

Reported	Date of Potential Lightning-Related Incident	State	Type of Strike (Direct or Indirect)	Bonded/ Grounded	Arc to	Chimney	Location	Path of Electricity	Date Installed or Date of Construction
			fire.			initial inspection.			
81	08/08/2010	MS	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
82	09/01/2010	TX	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.	Unknown.
83	01/09/2003	IN	direct	Unknown.	foil-back insul	hole near chimney	2nd Fl	Unknown.	Unknown.
84	23/09/2006	OK	direct	Unknown.	Unknown		Attic	Unknown.	Unknown.
85	10/10/2006	TX	direct	Unknown.	BIP	hole near chimney	Attic	Unknown.	Unknown.
86	14/06/2007	NC	Unknown.	Unknown.	Duct		Basement	Unknown.	Unknown.
87	20/06/2007	PA	Unknown.	Unknown.	Unknown		Basement	Unknown.	2000
88	20/06/2007	PA	Unknown.	Unknown.	Unkown		1st Fl	Unknown.	1999
89	20/06/2007	PA	Unknown.	Unknown.	copper pipe		Basement	Unknown.	2006
90	23/07/2007	TX	Unknown.	Unknown.	Elect lite		Attic	Unknown.	2005
91	28/07/2007	VA	Unknown.	Unknown.			Basement	Unknown.	Unknown.
92	17/08/2007	PA	direct	Unknown.	clamp		Basement	Unknown.	Unknown.
93	22/08/2007	OH	Unknown.	Unknown.	Elect		Basement	Unknown.	2006
94	30/09/2007	NE	direct	Unknown.	Cable		Basement	Unknown.	2006
95	14/12/2007	TX	direct	Unknown.			2nd Fl	Unknown.	2005
96	16/02/2008	TX	direct	Unknown.	Elect	hole near chimney	2nd Fl	Unknown.	2002
97	20/05/2008	GA	Unknown.	Unknown.	Elect		Basement	Unknown.	2004
98	23/05/2008	NE	Unknown.	Unknown.	BIP		Basement	Unknown.	1950
99	03/06/2008	VA	Unknown.	Unknown.	Elect		Basement	Unknown.	2004
100	09/06/2008	NC	Unknown.	Unknown.	bolt		Basement	Unknown.	2008
101	13/06/2008	KY	Unknown.	Unknown.	copper pipe		Basement	Unknown.	2004
102	08/07/2008	IN	Unknown.	bonded	Unknown		Basement	Unknown.	Unknown.
103	08/07/2008	OK	Unknown.	Unknown.	Elect	hole near chimney	Attic	Unknown.	2006
104	15/07/2008	NE	Unknown.	Unknown.	Elect		Basement	Unknown.	2008
105	27/07/2008	PA	direct	Unknown.	Unknown		Basement	Unknown.	Unknown.
106	27/07/2008	NJ	Unknown.	Unknown.	Unknown	hole near chimney	1st Fl	Unknown.	2008
107	27/07/2008	NJ	Unknown.	Unknown.	Elect	hole near chimney	Attic	Unknown.	Unknown.
108	07/08/2008	SC	Unknown.	Unknown.	Elect	hole near chimney	Attic	Unknown.	Unknown.

Reported	Date of Potential Lightning-Related Incident	State	Type of Strike (Direct or Indirect)	Bonded/ Grounded	Arc to	Chimney	Location	Path of Electricity	Date Installed or Date of Construction
109	27/08/2008	NE	direct	bonded	Duct/Romex	hole near chimney	Basement	Unknown.	1/1/02
110	28/08/2008	IA	Unknown.	Unknown.	Unknown		Attic	Unknown.	Unknown.
111	09/09/2008	PA	direct	Unknown.	Unknown		Basement	Unknown.	2002
112	17/05/2009	GA	Unknown.	Unknown.	Elect		Basement	Unknown.	1970
113	27/05/2009	KY	direct	Unknown.	copper pipe		Basement	Unknown.	2005
114	01/06/2009	OH	Unknown.	Unknown.	Duct		Basement	Unknown.	2006
115	14/06/2009	SC	Unknown.	Unknown.	Unknown		Basement	Unknown.	Unknown.
116	26/06/2009	CT	Unknown.	Unknown.	Elect		Basement	Unknown.	Unknown.
117	01/07/2009	FL	direct	bonded	Elect	hole near chimney	Attic	Unknown.	2001
118	13/07/2009	SC	direct	bonded	elect		Attic	Unknown.	2007
119	23/07/2009	MD	Unknown.	Unknown.	strap / duct		Basement	Unknown.	2006
120	04/08/2009	KY	Unknown.	Unknown.	?	hole near chimney		Unknown.	Unknown.
121	04/08/2009	SC	Unknown.	Unknown.	Duct/clamp		Basement	Unknown.	2005
122	05/08/2009	GA	Unknown.	Unknown.	Elect	hole near chimney	Basement	Unknown.	Unknown.
123	21/08/2009	GA	Unknown.	Unknown.	A/C line		Basement	Unknown.	2003
124	21/09/2009	OK	direct	bonded	Elect		Attic	Unknown.	2007
125	01/01/2010	KY	Unknown.	Unknown.	Unknown		1st Fl	Unknown.	Unknown.
126	11/03/2010	IN	Unknown.	bonded	Unknown		Attic	Unknown.	2002
127	06/04/2010	OK	direct	Unknown.	Elect		Basement	Unknown.	2007
128	30/04/2010	MO	Unknown.	Unknown.	Elect		Basement	Unknown.	2001
129	14/05/2010	NJ	Unknown.	Unknown.	duct		Basement	Unknown.	2004
130	16/05/2010	AR	direct	bonded	elect		Attic	Unknown.	2005
131	16/05/2010	NC	direct	Unknown.	Elect		1st Fl	Unknown.	2000
132	21/05/2010	GA	Unknown.	Unknown.	copper pipe		1st Fl	Unknown.	2008
133	31/05/2010	OK	direct	bonded	Elect		Attic	Unknown.	2008
134	05/06/2010	PA	Unknown.	Unknown.	Unknown		1st Fl	Unknown.	2006
135	22/06/2010	SC	Unknown.	Unknown.	Unknown		Basement	Unknown.	2005
136	24/06/2010	PA	direct	Unknown.	Unknown	hole near chimney	Basement	Unknown.	2003
137	21/07/2010	IN	direct	bonded	Duct	hole near chimney	Basement	Unknown.	2007
138	21/07/2010	CT	Unknown.	Unknown.	Elect		Basement	Unknown.	2006
139	27/07/2010	NC	Unknown.	Unknown.	Ext Flash		Basement	Unknown.	2005

Reported	Date of Potential Lightning-Related Incident	State	Type of Strike (Direct or Indirect)	Bonded/ Grounded	Arc to	Chimney	Location	Path of Electricity	Date Installed or Date of Construction
140	02/08/2010	NE	direct	Unknown.	Duct	hole near chimney	Basement	Unknown.	2005
141	11/10/2010	TX	direct	Unknown.	Elect	hole near chimney	Attic	Unknown.	Unknown.

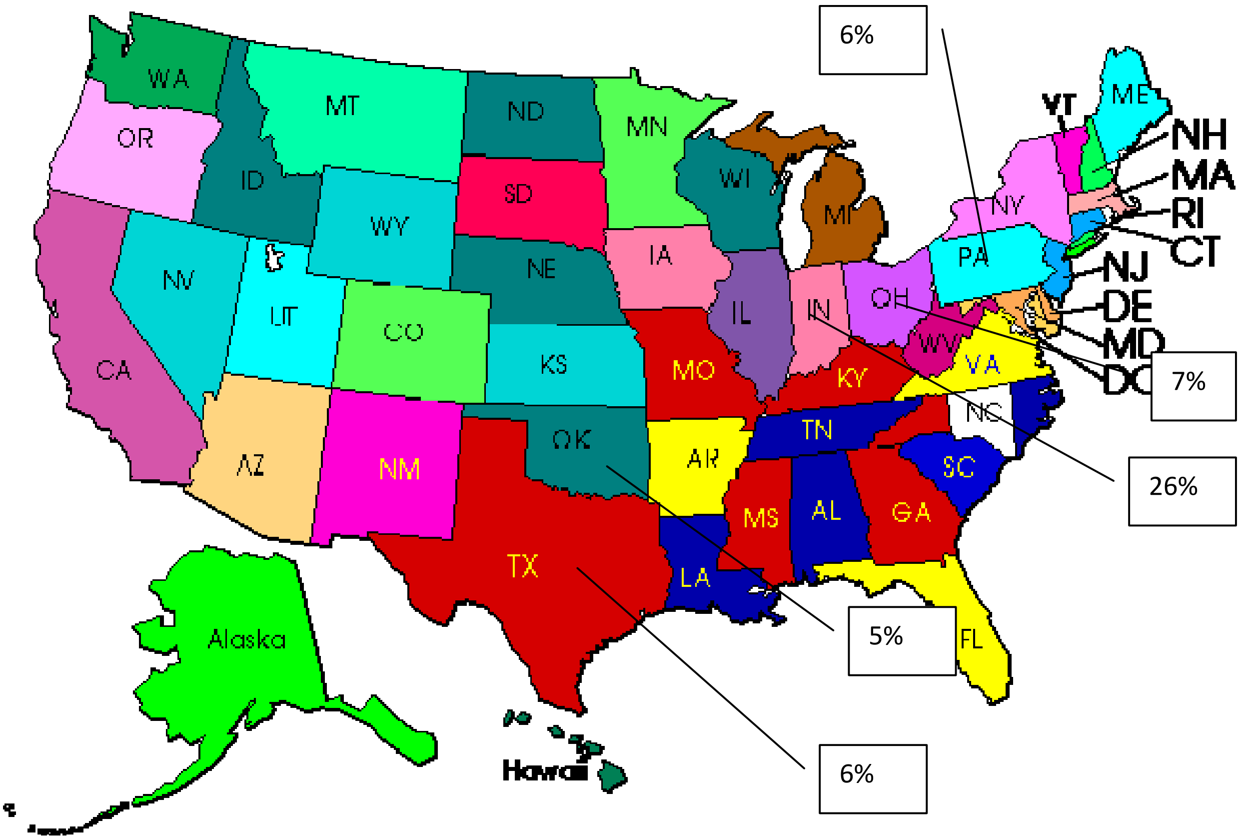
141 Incidents Involving CSST

We were unsure if the incident list presented above included the cases for which details are provided in Annex 3, or if the detailed cases given in the annex are partially included in the list. We have decided to not include specifically in the table above the detailed incident list from the Annex 3. The list above is large enough by itself to present a statistical interest. This table leads to the following geographical spread reported in a table format (we have indicated in bold type the states that have a significant number of incidents, i.e. more than 5%):

US State:	Abbreviation	Number of incidents reported	%
Alabama	AL	0	0%
Alaska	AK	1	1%
Arizona	AZ	0	0%
Arkansas	AR	3	2%
California	CA	0	0%
Colorado	CO	1	1%
Connecticut	CT	4	3%
Delaware	DE	0	0%
Florida	FL	4	3%
Georgia	GA	6	4%
Hawaii	HI	0	0%
Idaho	ID	0	0%
Illinois	IL	1	1%

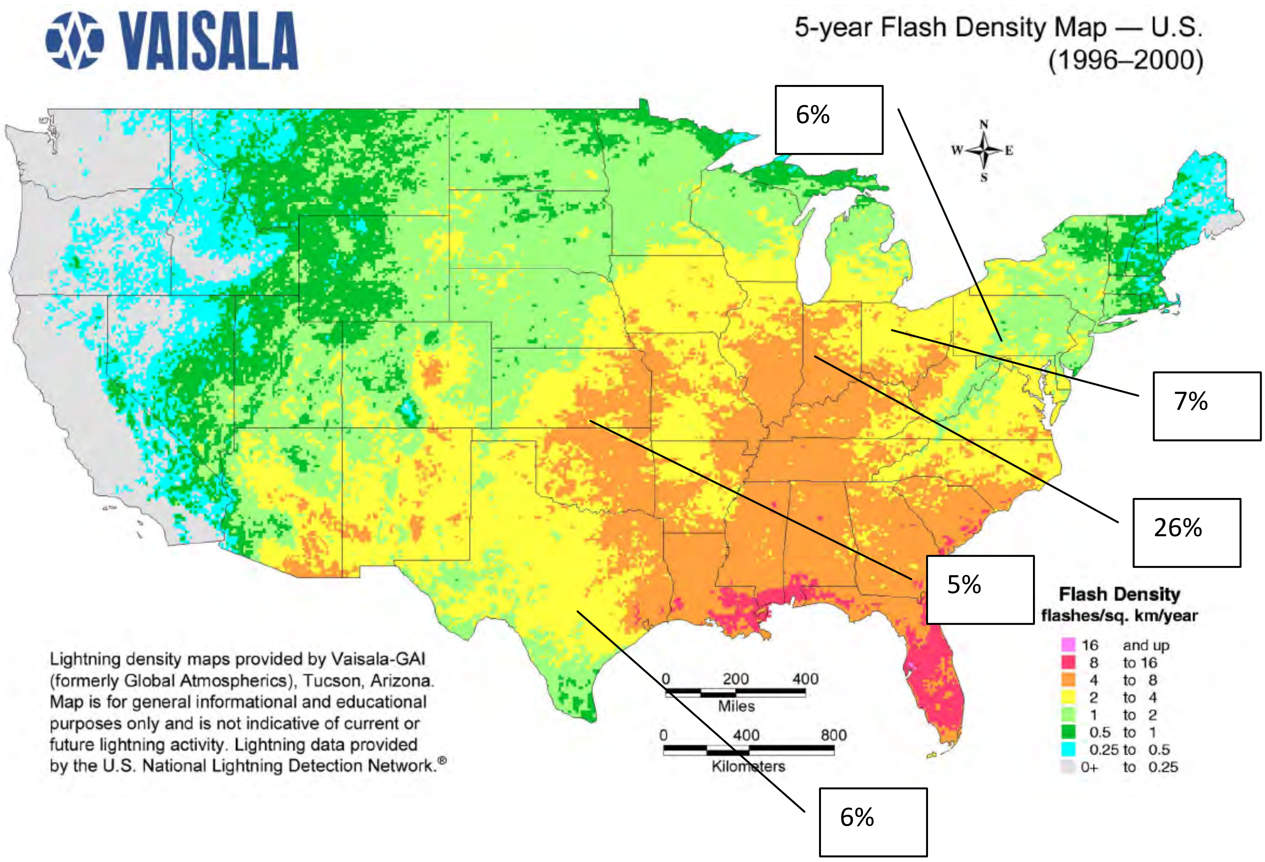
US State:	Abbreviation	Number of incidents reported	%
Indiana	**IN**	37	**26%**
Iowa	IA	1	1%
Kansas	KS	2	1%
Kentucky	KY	5	4%
Louisiana	LA	0	0%
Maine	ME	0	0%
Maryland	MD	2	1%
Massachusetts	MA	0	0%
Michigan	MI	2	1%
Minnesota	MN	3	2%
Mississippi	MS	1	1%
Missouri	MO	3	2%
Montana	MT	1	1%
Nebraska	NE	5	4%
Nevada	NV	0	0%
New Hampshire	NH	0	0%
New Jersey	NJ	4	3%
New Mexico	NM	0	0%
New York	NY	2	1%
North Carolina	NC	6	4%
North Dakota	ND	0	0%
Ohio	**OH**	10	**7%**
Oklahoma	**OK**	7	**5%**
Oregon	OR	0	0%
Pennsylvania	**PA**	9	**6%**
Rhode Island	RI	0	0%
South Carolina	SC	6	4%
South Dakota	SD	0	0%
Tennessee	TN	0	0%
Texas	**TX**	9	**6%**
Utah	UT	0	0%
Vermont	VT	0	0%
Virginia	VA	4	3%
Washington	WA	0	0%
West Virginia	WV	0	0%
Wisconsin	WI	1	1%
Wyoming	WY	1	1%
	Total	**141**	**100%**

Geographical Distribution of the 141 Cases



Geographical Distribution of the 141 Cases Showing States Where 5% or More of the Cases Are Concentrated

We have also reported below these figures on the lightning activity map:



Geographical Distribution of the 141 Cases Showing States Where 5% or More of the Cases Are Concentrated, Drawn on the Keraunic Map

Once again the correlation between lightning activity and CCST reported incidents is not clear. Indiana shows a lot of lightning activity with the largest amount of CSST damages (27%). But Oklahoma has almost the same lightning activity with only 5% of reported incidents.

<u>In order to draw any meaningful correlation between incidents reported and lightning flash density, a greater number of data sources must be incorporated and correlation with the length of CSST installed must be considered.</u>

It appears that at least some of the detailed events listed in Annex 3 are not listed in the table above. It is also acknowledged that there are other data sources that have not been provided (such as insurance data, court cases, and so forth) that may contain other incidents not included. We also note that there are no cases included in the list that occurred in the State of Louisiana; a state with what appears to be the second highest incidence of flash-to-ground density in the US. It is highly unlikely that there have been no CSST incidents in Louisiana, even though many homes there were protected as a part of the class action lawsuit. In comparison, 37 incidents were reported in Indiana.

The reason for having more incidents reported in Indiana than anywhere else could be related to the fact that one incident in Indiana, described in Annex 3, led to training of Indiana fire departments regarding CSST. Thus they may be more aware of the possibility of CSST-related incidents than fire departments in other states. It has been already discussed that NFIRS doesn't include a CSST coding and discussion with experts have shown that, when contacted, many fire inspectors were not aware of CSST and its potential involvement in some incidents.

Furthermore, in Annex 3, six incidents are reported in one community in Florida, yet the database given in the table above only lists four incidents in the entire state of Florida. So, according to some experts, the statistics given above are almost certainly underreported.

<u>For these reasons, drawing any general conclusion from the statistics listed in the above tables may be misleading.</u>

4.1.2. INSURANCE COMPANIES

State Farm has been contacted, and no information has been provided at time of writing this report.

Allstate has also acknowledged the information request but has not yet forwarded any incident reports or statistical elements.

The Insurance Information Institute was expected to provide some data, but no information has been provided at time of writing this report.

At the date of finalizing our report, nothing has been received.

Note:

The only information received came from an expert who reported: “Number of lightning insurance claims per year >200,000.”

As pointed out by one of the CSST manufacturers, the number of fire incidents in which lightning and CSST were involved are not that high in comparison to other causes or combinations of causes. However, the total dollar value of the consequences of such fires is likely to be more significant. However, the lack of insurance company data and feedback has prevented us from further, more detailed factual investigation.

Note:

We also received the following comment:

“While the current study of safety has been confined within the context of lightning strikes, safety must also be considered in the broader context of general usage. There are no known documented cases of loss of life related to any physical or operational failures of CSST product or systems, while the same cannot be said for other gas piping systems. CSST has already been demonstrated to be a safe product, and the objective of the research should only be focused on whether there is an incremental reduction of safety due to lightning strikes. In our opinion and based on actual statistical data from the NFPA, the damage to CSST caused by lightning strikes has been grossly overstated, and represents (at best) a marginal (if not statistically insignificant) reduction in safety compared to other gas piping products.

… [this source] believes that many organizations are asking the wrong questions and/or looking to the wrong solutions to the problem.

Let us state for the record that the lightning related problems of CSST has been incorrectly characterized while the prescribed bonding solution has been overly simplified …

Although the bonding of the CSST system alone is considered “better than nothing,” it is not considered a complete solution to the threat of lightning damage to a building. Bonding CSST alone ignores the more conventional and comprehensive approach of equipotential bonding and/or the installation of a lightning protection system. Bonding represents a partial solution that is intended to provide passive resistance to any lightning energy that enters the premise from an indirect strike. It should also be understood that in the absence of a properly installed lightning protection system, a direct lightning strike to the structure is beyond the ability of any man-made system and/or equipment to absolutely protect the building and its contents from severe damage. Unless CSST bonding is examined and evaluated within the broader context of protecting the structure and all metallic systems within that structure, the outcome of this research will only confirm what is already known: bonding of CSST alone, without consideration of other metal systems in the building, is less than a complete solution.

… The relative damage associated with CSST and lightning pales by comparison to other content within the home and/or to the wooden structure itself

This estimated annual number of CSST fires compared to all residential fires for all causes in the United States does not even register as a whole number and represents less than 0.01 of 1 percent of the total. There appears to be a gross misplacement of concern when one considers that over the same time period, the number of lightning caused fires within the electrical distribution system within residential structures was approximately double (240 incidents per year) the number of natural gas fires.”

These statements, as well as many others received, tend to show that CSST incidents are small in quantity compared to other sources of damage, and that indirect lightning protection should address all sources of damage and not only CSST. However, the present study is focused by request on the efficiency of CSST bonding so the report will concentrate only on CCST incidents and possible remedies.

Note:

Another expert declared: "many lightning experts agree with the statement that to protect against damage from a direct strike, a lightning protection system with comprehensive equipotential bonding is necessary."

Preliminary conclusions: not enough data was provided by insurances companies to draw conclusions.

4.1.3. STATE FIRE MARSHALS

The State Fire Marshal Offices of all 50 states, the District of Columbia, and Guam were contacted. The feedback ranged from none, to a few incident reports, to direct access to the NFIRS database through the data entry tool. Unfortunately, as previously mentioned the CSST issue has not been coded in the system with a specific entry code. Though there is a “remark” box; it is often mentioned as to be very seldom used.

Preliminary conclusion: the information which can be extracted from the national database reveals itself as not very relevant for the current study.

4.1.4. THE CSST MARKET

The total number of feet of CSST sold and installed in the United States has been provided through AHRI based on collected data from the various manufacturers.

Years	Total Feet
1997	11 908 932
1998	20 772 050
1999	30 948 107
2000	38 761 600
2001	46 374 204
2002	55 063 138
2003	64 693 211
2004	79 120 055
2005	93 506 066
2006	95 434 996
2007	82 047 667
2008	58 312 480
2009	40 172 804
Total	717 115 310

Yearly Distribution of CSST Market

We can also find other elements regarding CSST market in various publications. They are consistent with the AHRI statistics.

[*10*: *2003, The CSST Battle Is Over.pdf*] "The CSST product has been used in Japan and Europe since 1980, and was introduced in the USA in 1989. The International Association of Plumbing and Mechanical Officials approved CSST for inclusion in its 2003 Uniform Plumbing Code which opened the doors for CSST in all 50 states."

[*134*: *The Wholesaler - March 2009.pdf*] "Gastite vice president-marketing Craig Barry indicated that: 'CSST has revolutionized the gas-distribution business. CSST is easy to use and this lowers the cost over the entire installation. Back-breaking black iron pipe projects that demanded eight or 10 laborers can now be handled with ease by only one or two certified CSST installers — freeing up precious labor for other tasks that will keep your project moving forward. Lightweight and flexible Gastite CSST will typically slash installation time by 50% or more.'"

[*151*: *Cozen CCST.pdf*] "In 2004, about 55% of U.S. homes were heated with natural gas. The CSST market is quite impressive."

[*120*: *NAHB CSST Toolbase.pdf*] "Since 1989, 150 million feet of CSST have been installed in residential, commercial, and industrial structures. In 2002, 45 million feet of CSST was sold and installed in the United States."

[*16*: *2006 01Gastite Move Plant.pdf*] "In 2005, overall industry shipments of CSST were at around 100 million feet."

[*56*: *2010 10 Cozen CSST Omegaflex.pdf*] "To date, 750 million of feet of CSST have been sold across the United States."

4.2. Documentation of the mechanisms involved in reported CSST incidents in incident databases, manufacturers' records, published results of formal investigations, news reports, and other sources, noting the limitations in such data

4.2.1. GOODSON REPORTS

One of the only public reports regarding failure of CSST studied in a scientific way is given in [*125 : p.379, Goodson Gasline and Lightning.pdf]*; another version was published later in 2005 with the same authors and almost the same content.

The authors state: "Corrugated Stainless Steel Tubing (CSST) represents a relatively new technology for delivering fuel gas within a residential or commercial structure. The flexible thin walls of CSST present a problem in terms of the propensity of CSST to fail when exposed to electrical insult, particularly lightning."

This paper presents theoretical basis for CSST failures caused by lightning, as well as investigative techniques to be used when examining a fire scene.

"CSST is recognized by ANSI / IAS LC-1 -19971. CSST is sheathed by a polymer conformal coating. CSST is made by 6 manufacturers. Manufacturers and ANSI LC-1 require a potential installer to take a several hour installation course.
CSST was recognized in the Fuel Gas Code (NFPA 54) in 1988. The IAPMO (International Association of Plumbing and Mechanical Officials)) rejected CSST for reasons of safety in 2000 but later approved the use of CSST in 2003."

The authors indicate that CSST is cut to length. The way termination is then made on site may be in question, since experience in the lightning protection industry shows that sometimes the termination is the weaker part of a lightning protection system. This is not relevant to the study, since the damages are not located at the termination. However, South Korea is focusing most on termination when trying to avoid problems in the field. Manipulation of CSST may need to be studied. This is apparently more a concern abroad than in the US, where manufacturer specifications explain how to use the product (maximum bending, avoiding contact with nails and sharp points, training of contractors, etc.).

The authors indicate: “Amount of energy for a conventional ½” black pipe will require ~15 times the energy that would be required to similarly melt CSST.”

For a direct impact, it is well known that the increase of temperature due to the arc foot is more important than the Joule effect due to the current flow (see IEC 62305-1 for equations and scientific background).

“Lightning fast wave fronts may cause problem (corrugated surface). New house construction observed has shown very tight bends and routing of CSST immediately adjacent to large grounded surfaces."

"Testing of CSST under actual installed conditions using transient waveforms may well show further limitations that conventional bonding and grounding cannot accommodate.”

"Frisco Fire Department Report lists escaping gas from the end connectors during lightning events as being possible sources of ignition."

"If a copper wire arced to the stainless steel tubing, there should be copper remnants found. There is no need for a strike fax.”

The authors provide valuable input, and it is rather disappointing that we haven’t been able to get more accurate data from their database at the date of this report.

First of all, they clearly indicate that for what he has observed, power fault may not be the only source of damage. These findings are consistent with statistics of damage provided above. They also mention that a strike fax analysis is not needed and that visual analysis of CSST may be sufficient to confirm lightning involvement.

They question the fact that termination may be involved in damages (see comments regarding South Korea) and state that the corrugated shape and bending of CSST also need to be studied regarding the high frequency effect of lightning. Adjacent holes are also mentioned which may be related to this high frequency behavior.

Note: A list of a limited number of annotated incidents is provided in Annex 3. However, important details are missing in all of those reports which prevent us from deriving valid factual conclusions. The three cases documented by Goodson in his reports are also included in the annex.

> Note:
> The following comment has also been provided to us showing how the hole on CSST may be interpreted: “Stainless steel (used in CSST) is not prone to melt during a fire because of its high melting point. So, if an arced hole is found in a CSST line after a fire, which is preceded by lightning (as verified by positive lightning reports), and the arcing was not caused by an energized wire contacting the CSST, then the process of elimination leaves lightning as the probable culprit.”

4.2.2. LAW FIRMS

[*83*: *CSST Task Force*] Cozen O'Connor created the CSST Task Force to focus on the opportunities presented by lightning-induced corrugated stainless steel tubing (CSST) failures. Different court actions are still in progress. Various extensive confidentiality agreements are attached to former cases. Therefore, it has been impossible so far to receive very detailed information about fires in which CSST failures were present.

[*56: 2010 10 Cozen CSST Omegaflex.pdf*] Very recently, the first case involving CSST went all way through litigation. The jury recognized full liability for the CSST manufacturer. Documents related to that case have not been made public.

4.3. Research Studies on the performance of CSST in the presence of lightning energy

The main document provided to support introduction of the requirement of bonding of CSST in NFPA 54 is [*71*: *Bonding Effectiveness Aug 2007.pdf*] by Brian Kraft and Robert Torbin.

Tests were performed by LTI for Titeflex Corporation.

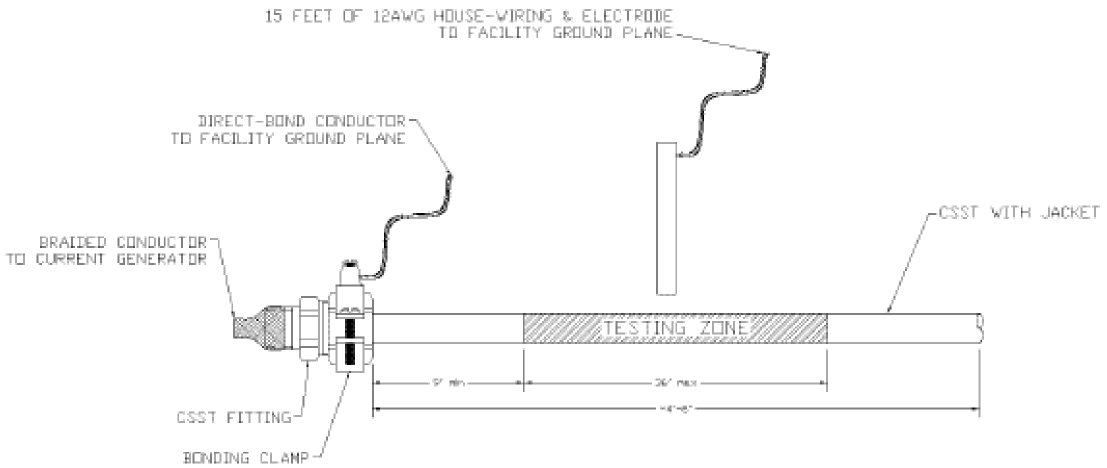
"Gas piping systems must be bonded to the grounding system in accordance with the NEC. Traditionally, the means for bonding of gas piping has been the equipment grounding conductor when the piping is attached to equipment that is electrically powered. However, the requirement for bonding when the gas equipment is not electrically powered is addressed by the *NEC*.

The premise electrical panel incorporates a grounding system, commonly through a grounding electrode conductor and buried electrodes/rods. This provides the electrical ground specific to that building, and is referred to as the house ground.

It should be noted that the *NEC* does not require direct bonding for all metallic systems, nor does it effectively address lightning protection which is considered out-of-scope.

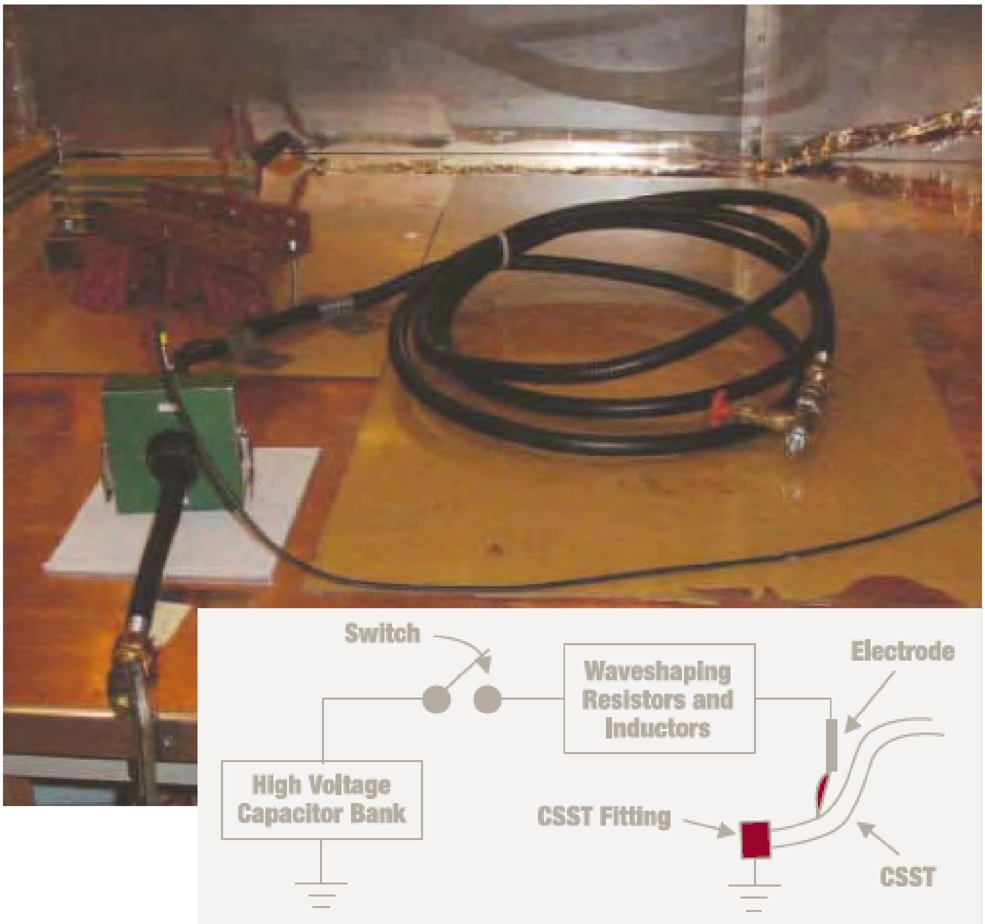
The laboratory testing program was only intended to allow relative comparisons of alternative bonding techniques. The recommended bonding technique should not be considered a definitive protective measure against all lightning strikes nor construed as an optimum level of bonding."

The test layout is summarized in the figure below. The generator was connected between one end of the CSST sample and the facility ground plane. There are two return paths to ground: one through the CSST fitting and one through an arc between the CSST and an electrode representing a grounded metal part of the installation.



Test Layout Scheme

"A 10/300 waveshape was used." This waveshape is very similar to the 10/350 µs waveshape defined in IEC 62305-1 for testing both LPS components and equipotential bonding SPDs.



Test Layout Picture

"The only conclusion that can be reached is that fairly high voltage levels, in the order of thousands of volts, are required to initiate an arc.

The non-bonded configuration was the only configuration examined where the arc generated perforations through the tubing wall.

It is very interesting to note the total lack of arcing with the 10 ft of #6 AWG bond configuration. This bond configuration presented the lowest impedance path to ground of any of the configurations examined in this study. Further studies are recommended.

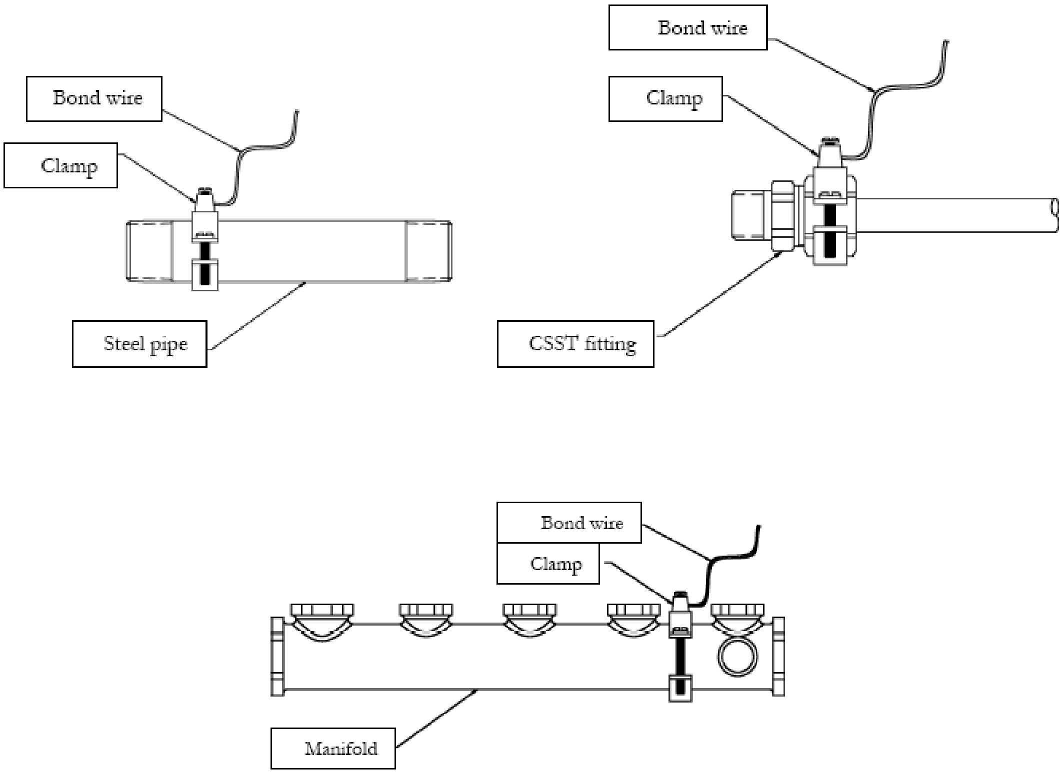
The *NEC* requires that all electrically conductive materials (which potentially includes all metallic piping, ducts, vents, coax cable etc.) be bonded together in a manner that establishes an effective (low impedance) ground-fault current path.

To implement direct bonding methods in the field, a set of installation instructions have been developed and will be used to provide guidance to electrical contractors who generally install the bonding means and to electrical inspectors who are responsible for insuring that the bonding is properly installed.

Recommendations: based on the results of the testing and the analyses of that data, the appropriate fuel gas and electrical codes should be amended to require the direct boding of all metallic piping in residential construction. This process has been initiated with a proposal to the *National Fuel Gas Code*. The code change process is long and complex, and it is recommended that a committee of interested parties be formed to monitor the process to its conclusion.

These requirements shall apply to all new CSST installations **as well as partial retrofits** of CSST to existing steel pipe and copper tubing systems. Direct bonding of existing CSST systems shall not be retroactively enforced. These requirements are provided as part of the manufacturer's general instructions for single-family, multi-family and certain commercial buildings.

Bonding/grounding clamps shall be listed to UL 467 or other acceptable national standards. The corrugated stainless steel tubing portion of the gas piping system shall not be used as the point of attachment of the bonding clamp at any location along its length. The bonding clamp shall be attached such that metal to metal contact is achieved with the steel pipe component or CSST fitting."



Possible CSST Bondings

The way the tests are made shows that they are mainly typical of lightning stress coming from outside of the house; the source is near the entrance bonding point of the CSST. In fact, there are two parallel paths. One is the more direct route and is from the generator through the CSST fitting grounding. The second path is potentially through an arc created between the electrode simulating a metallic grounded part and the CSST. The creation of an arc depends on the generator characteristics (mainly its peak current and front of the wave) and on the length of bonding conductor.

When the impedance is high enough (i.e. the bonding conductor is long enough) the voltage between the CSST and ground plate is high enough to spark over between the electrode and the CSST. These tests have shown that there is no sparkover with a 10 ft bonding conductor, and that a sparkover appears with a bonding conductor of over 20 ft. Furthermore, the arc is intermittent for a 20 ft#6 AWG (13 mm^2) bonding conductor and permanent for a 20 ft #8 AWG (9 mm^2) one. The smaller the cross section of the 20 ft conductor, the higher its resistance is. The voltage drop is then greater for the #8 AWG than for the #6 AWG. It is worth noting that the length limit is between 10 and 20 ft when the length of the conductor between the electrode and the ground plate is 15 ft.

The impedance of the CSST should have been involved by connecting the bonding connector at different locations along the CSST. This would add additional relevance to the tests. The voltage drop along the CSST would have added to the voltage drop along the bonding conductor, which would have probably led to sparkover for smaller lengths of bonding conductor and/or for larger cross sections of the bonding conductor.

In addition, possible heating in the CSST due to lightning current flow would have been demonstrated by such tests.

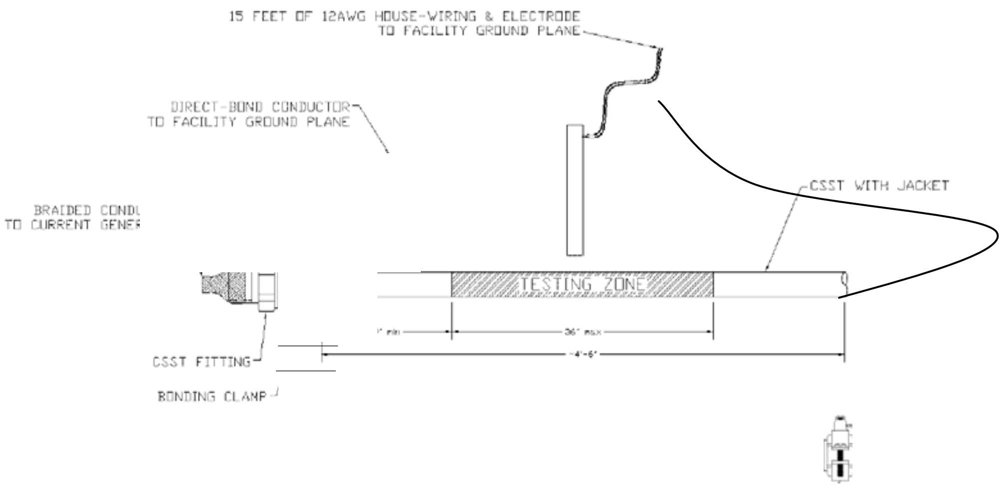
Table 2: Test Results Summary, Test Sample

Test Set-Up	Results		CSST Current (kA)			CSST Charge (C)		
	Arced	Hole	Min	Max	% of Generator	Min	Max	% of Generator
No Bond	i	Yes	2.30	4.65	96	1.10	1.95	98
10-ft, 6AWG	No	No	---	---	---	---	---	---
20-ft, 6AWG	i	No	1.40	3.95	40	0.08	0.37	8
40-ft, 6AWG	i	No	1.15	7.80	57	0.10	0.88	21
20-ft, 8AWG	Yes	No	2.30	4.25	45	0.25	0.49	13
40-ft, 8AWG	Yes	No	3.10	5.60	60	0.37	0.77	20

Legend: i: intermittent

Results for Tests Performed by LTI for Titeflex Corporation (see [71])

A suggested test layout for future tests is described below. It aims to better demonstrate the influence of the CSST impedance and to be more relevant to all types of lightning stresses, not exclusively limited to stress coming from the gas supply. Furthermore, we suggest the use of a test generator capable of generating a steeper front of the wave (typical of the second impulse in a multiple impulse lightning strike. The 10/300 impulse is more typical of a direct lightning impact, as mentioned above). This might be a challenge, since the length of CSST and of the#6 AWG bonding conductor will probably have a major influence on the generator output. The target could be met by using computer simulations combined with laboratory tests.



Suggested Test Layout

Note: A test report for a CSST specifically designed to withstand an enhanced lightning surge has been provided to us. It already includes a distance between the generator input and the grounding point of CSST. Furthermore, the arc is directly created between the generator input and CSST; consequently, the full generator current flows through the arc and then along the CSST. This test report shows impressive results regarding lightning surge withstand. No damage occurs with 10/1000 impulse, and only waves used in aeronautics are creating holes (and only for the highest tested values).

Another test report on another brand of CSST also gives interesting results when comparing regular CSST to a CSST specifically designed to have an enhanced lightning surge withstand. In that case the test circuit also is closer to what we suggested above (distance between electrodes connected to generator and grounded part of the sample). For that test report, the generator current also is directly injected in the arc created by the electrode. The main difference between this report and the previous one is that the tail of the waveshape is shorter than the 10/1000 waveshape used in the earlier test. However, the test report indicates that they succeeded in creating with this waveform the same effects as reported from the field experience.

The table below shows the values of peak current and of the current derivative "di/dt" for various types of impulses. The highest di/dt is obtained for subsequent negative short impulses.

Tabulated values of lightning current parameters taken from CIGRE (Electra No. 41 or No. 69*)

Parameter	Fixed values for LPL I	Values			Type of stroke
		95 %	50 %	5 %	
I (kA)		4(98 %)	20(80 %)	90	First negative short
	50	4,9	11,8	28,6	Subsequent negative short
	200	4,6	35	250	First positive short (single)
di/dt_{max}		9,1	24,3	65	First negative short
(kA/µs)		9,9	39,9	161,5	Subsequent negative short
	20	0,2	2,4	32	First positive short

di/dt Values Given in IEC 62305-1

Document [*71*: *Bonding Effectiveness Aug 2007.pdf*] has been updated and expanded in [*121*: *NEC_Lightning_Report-rev2.pdf*], published two years later. The test layout remains the same.

In that document, the problem of proximity between CSST and other metallic systems (not only the power lines) is introduced.

"The bonding of CSST must be performed in accordance with the *National Electrical Code,* the *National Fuel Gas Code,* and the manufacturer's installation instructions to provide the maximum achievable protection from arcing damage resulting from differences in potential between metallic systems in close proximity to each other, and based on the manner in which these systems are bonded to the grounding electrode system."

This report addresses not only indirect lightning but also power faults (250 A, 4s).

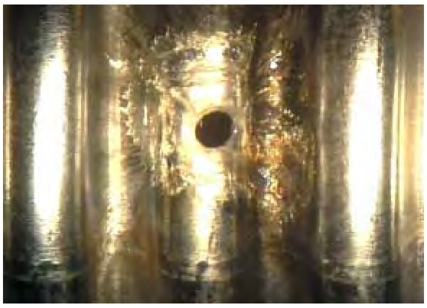
The conclusions are in line with the previous report:

"• CSST can withstand (without failure) expected ground faults imposed by the electrical system.

• CSST will provide an effective, low-impedance conductive pathway to ground when it is energized by the electrical service or an indirect lightning strike.

• For indirect lightning strikes, direct bonding will reduce or eliminate the damage resulting from electrical arcing between the CSST and another metallic system in close proximity by eliminating or reducing the difference in electrical potential.

• All CSST systems should be directly bonded to the grounding electrode system using a#6 AWG or larger copper wire in addition to any "self-bonding" provided through the equipment grounding conductor."

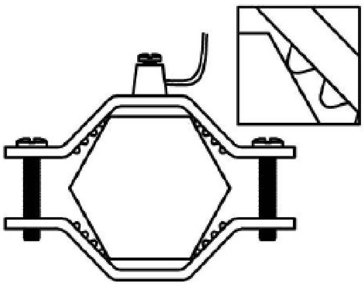


Example of Arcing Damage observed after the Test

The clamp effectiveness is addressed too:

"The intended purpose of attaching bonding clamps to the CSST fittings is to provide a dedicated, permanent connection between the gas piping system and a low impedance conductor that is connected to the electrical ground system.

It had been previously determined that a bond connection directly to the tubing itself would prove to be unacceptable because of the lack of mechanical robustness associated with the thin tubing wall and the lack of a uniform corrugation profile between the different CSST brands. The brass, hex-shaped fittings provide a much more mechanically stable and electrically conductive platform for making the bonding connection."



CSST Bonding on Hex-Shaped Fittings

"If the difference in resistance between the clamp on round pipe and the clamp on a CSST fitting is small, there would be essentially no difference in the performance of the bonding connection

The ranges of electrical resistance for the CSST fitting connection and the pipe connection were found to be sufficiently similar to establish a good correlation and equivalency based on electrical resistance. This establishes comparable performance between the hex-shaped CSST fitting attachment and conventional industry-accepted bonding practices on round pipe"

Other tests are described in [*106*: *JLightConstrJuly2004.pdf*] but with limited details.

Tests were performed at 15 kV on a dedicated CSST product called Counter Strike (Omegaflex) designed specifically to have a better lightning stress withstand than regular CSST. No hole was observed in that case.

No information about the generator used was provided, making the document useless for our study.

More tests can be found in [*129*: *PlumbingEngineerSeptember2010.doc*]

The tested product in this document is called FlashShield^{TM}; it is a dedicated CSST product from another manufacturer also designed specifically to better withstand lightning stress. It has two layers of semi conductive material around an aluminum mesh (like that used for lightning protection on aircraft). Testing was carried out with various types of current: return stroke current, intermediate current, and continuing current: 45 kA and an action integral of 56 000 A^2s. The product was also tested according to ANSI LC1 standard.

FlashShield Picture

It is interesting that the product was able to withstand a return stroke current (impulse current) as well as a continuing current; however, there are not enough data in the paper to draw additional conclusions.

The NAHB's report [*84*: *csst_lightningconcerns.pdf*] also addresses the efficiency and the need for bonding of CSST. It was a document provided to support the introduction of CSST bonding in NFPA 54.

"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.

Damage caused by a lightning strike to a CSST system can be described as small puncture of the tubing wall. 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 appears to be consistent around the country.

Example of Damage to CSST

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."

It is interesting to note that this report also recommends bonding at the service entrance to the building. What is observed in the field is that additional bonding is sometimes implemented, for instance, at the manifold. This report doesn't provide specific test results. It rather compares the evolution of the bonding requirements in NFPA 54 (*National Fuel Gas Code*) and NFPA 70 (*NEC*) as well as in the manufacturers' data sheets. The purpose of the report is mainly to support a common bonding practice among CSST manufacturers and to unify the wording among the manufacturers' data sheets and the various codes.

The following table traces how bonding measures have changed over time in the codes and in the manufacturers' data sheets

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

Compared Bonding Requirements (see [84])

The CounterStrike ™ product is presented in the report. It is a specific product which has been developed to address the induced lightning concern. The report concludes:

"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."

As described above, the tests were carried out on a specific product. The lack of more detailed data prevents us from further commenting on the tests. The product is specific and proprietary. As explained by NAHB, the bonding measures should also apply to this CSST product, the design of which would only enhance the level of protection.

It is interesting to note that in 2007, NAHB was referring to CounterStrike 1G (which required 'direct' bonding). That product has been superseded by CounterStrike 2G (which does not require 'direct' bonding). CounterStrike 2G is listed by the ICC-ES (PMG 1058) for installation without any additional bonding.

Document [*133*: *standards council decision.pdf*] summarizes the questions still not answered satisfactorily and opens discussion regarding proper location of bonding and potential necessary separation distance between CSST and other metal parts or conductors. These questions are important, as some new datasheets from manufacturers recommend a separation distance from other grounded elements. In addition, it has been noticed in some events that multiple bonding was present (at the installation entrance as well as, for example, at the manifold in the attic).

“The CSST Task Group concluded that a research program was necessary to identify safe methods for the installation of CSST to protect against lightning induced failure with consequent gas leakage.

- Validate **whether or not bonding** of CSST is an adequate solution to lightning exposure problem.
- If bonding is the solution, validate **how bonding should be done**.
- If bonding is the solution, validate **the size of the bonding jumpers**.
- Determine **if bonding should be done at a location or locations other than where the gas pipe enters the building**.
- Determine if alternate methods can be used for safe installation, i.e., **separation from other equipment**.”

The efficiency of the bonding is discussed in that document and in many others. However, it has been difficult to get published documented cases showing bonding and damages, although such documented cases intended for publication have been discussed with us as a part of this project.

[*133*: *standards council decision.pdf*] mentions, for instance:

“In addition, the CSST Task Group noted limited anecdotal reports concerning failures where the bonding of the installation may have complied with the current edition of NFPA 54. The CSST Task Group cautioned that the lack of detailed information or incident reports made assessment of these anecdotes impossible”

While [*82*: *CSST Article Cozen 29 July 2010.pdf*] states:

“At least one of the members observed failed CSST gas lines even in instances where the CSST was bonded per NFPA 54 and the manufacturer’s recommendation.”

Note:

One of the experts declared: “the lightning industry recognizes that a#6 AWG electrical grounding conductor is capable of carrying the lightning event to ground without being damaged.”

Note: Conductors that are to be used to carry a lightning event to ground need to be as short as possible, and routed in a STRAIGHT line with no sharp bends or curves. Lightning does NOT make sharp turns as it travels along the exterior of the conductor. It will arc to nearby objects at sharp bends.”

4.4. Product and installation information, including international codes and standards and manufacturers’ recommended installation methods (to include bonding, insulation, and spacing/location as mitigation methods)

To cover the previous issues, datasheets from the manufacturers provide guidance on how and where to make the CSST bonding. An example is given in the extract hereunder copied (more details on the manufacturer’s instructions are given in subsequent sections):

3. If the building to be piped is in a high lightning flash density area or a region with a high number of thunderstorm days per year, (Figure 4-22) consideration should be given to utilizing the Lightning Risk Assessment method given in Annex L of NFPA 780 for a determination of the need for a lightning protection system.

Notes:

a. If possible, avoid running the bonding jumper a long distance through the building. The connection should be as short as possible. Gas meter should be near the electrical service if possible. If not, the bond can be connected at any point near the electrical service per Figure 4-21.

b. Lightning induced voltages seeking ground are subject to impedance; consider utilizing a braided or stranded bonding jumper for greater surface area, rather than solid wire.

c. Upon completion of the conventional yellow-jacketed ***TracPipe***® Gas Piping System installation and prior to gas service initiation, check to see if the bonding has been completed.

d. Routing of gas piping should be as low in the structure as reasonably possible for best performance.

e. ***TracPipe***® CSST runs, including ***CounterStrike***®, should be installed with a bend radius of 8 inches or more whenever possible; this will reduce the possibility that energy will jump from the piping to other conductive surfaces.

Example of TracPipe/CounterStrike Data Sheet

A few examples of data sheets that request separation distance are also given below:

Gastite/FlashShield:

> 5 **CARE SHOULD BE TAKEN** when installing any type of fuel gas piping (including CSST, iron, or copper) to maintain as much separation as reasonably possible from other electrically conductive systems in the building. Refer to sec. 4.3 Routing, in the Gastite D&I Guide for installation techniques. Consult local building codes as to required separations for CSST from such conductive systems including metallic chimney liners, metallic appliance vents, metallic ducting and piping, and electrical cables. See for instance the Indiana Residential Code, section 675 IAC 14-4.3-155.5 Section G2411.1; gas pipe bonding.

> When supporting Gastite® CSST tubing runs, the use of other conductive metallic systems such as metallic appliance vents, metallic ducting and piping, and electrical cables must be avoided.
>
> Flash Shield When supporting FlashShield™ tubing runs, contact with other conductive metallic systems is acceptable.

> Care should be taken when installing vertical runs to maintain as much separation as reasonably possible from other electrically conductive systems in the building.
>
> Flash Shield There is no requirement to maintain separation from other electrically conductive systems when routing FlashShield™

Example of Gastite/FlashShield Data Sheet

However, to our knowledge the only document that gives values for the separation distance is the Indiana code, as mentioned in [*119*: *Midwest2008.pdf*] "In 2005, Indiana changed its code for new homes to require bonding and grounding procedures. Then, in April, Indiana officials revised the code to require at least a 2-inch gap between the CSST and any other kind of metal to prevent arcing, which can cause a fire."

The Indiana code states:

"Sec. 155.5. Delete the text of Section G241 1 .1 and add text to read as follows: All metal gas piping upstream from the equipment shutoff valve(s) shall be electrically continuous and shall be bonded to an effective ground-fault current path in accordance with Section E3509.7. Except where connected to appliances and at bonding connections, flexible metal gas corrugated stainless steel piping shall be isolated from metal gas piping, metal water piping, metal air ducts, metal structural framing, and all electrical wiring methods by a space separation of at least 2 inches. Table E3503.1, or the piping system listing requirements, shall be used to size the bonding conductor used to bond corrugated stainless steel gas tubing (CSST) to the electrical system. »

Note:

One expert commented on the Indiana code position:

"There is only one state (Indiana) that requires physical separation of CSST from other metallic systems because of lightning concerns. They require at least 50 mm of separation and place the responsibility of maintaining this separation on each and every affected trade. Oddly enough, Indiana does not mandate the bonding of CSST systems, and depends on physical separation to prevent arcing damage. However, bonding is being considered in the next edition of the state code.

Given that the US *NEC* does not mandate equipotential bonding of all metallic systems, physical separation will provide some additional protection from arcing, but only to the degree that the level of potential difference between the metallic systems is below 20,000 volts (otherwise the arc will jump the 50-mm gap and still attach itself the CSST). There is (of course) no way to limit the energy within these metallic systems or the potential differences regardless of the type of strike (direct or indirect). This is the least effective means to reduce arcing damage and is nearly impossible to enforce in the field (during construction) and is impossible to control after the home is occupied."

Note:

Regarding multiple bonding, an expert declared:

"All the fuel gas codes in the United States only require a single point of bonding given the fact that all gas piping systems must be electrically continuous. However, more than one bonding connection is permitted. The second point of attachment is usually left to the electrician or system designer, or is required as part of a lightning protection system (which is actually not required by the building code) depending on the location of the various metallic systems within the building (such as metal piping in an attic space).

The City of Frisco, TX does require multiple bonding connections for all CSST systems and depends on the system design and the operating pressure.

The CSST industry supports the single bond approach. Given that no bonding approach can fully protect the system from damage from a direct strike and given that the US *NEC* does not require equipotential bonding of all metallic systems, the single bonding approach is probably good enough most of the time especially for indirect strikes."

An extract of the Frisco city ordinance stipulates:

"Dual pressure systems using corrugated stainless steel tubing shall be bonded at the service entry and at the manifold."

Note:

Another expert indicated:

"The installation variability you are seeing around the country is no doubt due to … evolution of instructions in the first few years of this new direct-bonding requirement."

Note:

Regarding a CCST product specifically designed to enhance its lightning withstand capability, we got the following declaration:

"In 2010 we updated our Design & Installation Guide to include info on the new FlashShield CSST system. We do not have a manufacturer's requirement for direct-bonding of the FlashShield CSST system due to its design and capabilities. FlashShield is to be bonded in the normal manner and in the same way as black iron piping systems, using *National Electrical Code,* NFPA 70, Section 250.104, where equipment grounding conductors are permitted to serve as the bonding means."

The 'Gastite and FlashShield Design & Installation Guide' indicates:

> For single and multi-family structures, a single bond connection shall be made downstream of the individual gas meter for each housing unit and upstream of any CSST connection. The bonding conductor shall be no smaller than a 6 AWG copper wire or equivalent. The bonding jumper shall be attached in an ap-

Extract from Gastite/FlashShield Design and Installation Guide

4.4.1. THE CSST MANUFACTURERS

The manufacturers of CSST strongly refute the warnings issued by the Lightning Safety Alliance. Their products present no greater risk than alternative gas piping materials, according to Kevin Hoben, president and CEO of Omega Flex. "This product has been on the US market since 1989. No one has been able to attribute a death or an injury to lightning strikes affecting CSST. We would not be in business if the product was vulnerable to lightning," Hoben said in [*150*: *2008 02 001 Mechanical, lightning groups at odds over CSST.pdf*].
See also the discussion in Annex 3.

The main manufacturers of CSST in the US include the following:

Manufacturers	CSST Product
• OmegaFlex	Tracpipe, Counterstrike
• Parker-Hannifin Corp.	Parflex sold lately to Omegaflex
• Titeflex Corp.	Gastite, FlashShield
• Ward Manufacturing Inc.	Wardflex
• EasyFlex USA	EasyFlex
• Tru-Flex Metal Hose Corp.	Pro-Flex
• MetalFab, Inc.	Diamondback

The manufacturing process for CSST seems to be the same worldwide. The production starts from coils of stainless steel sheet. The flat stainless steel band is formed into a tube. It is then welded under controlled atmosphere. The pipe is then corrugated. It undergoes a thermal process to relieve the metal from the stress and structure modification created by the welding and corrugation processes. Some manufacturers consider that the specifics of their patented processes alleviate the need for any post-forming thermal treatment and therefore do not include that operation as part of their process. The corrugated pipe is then coiled. Each coil is water-pressure tested to check for any leaks. After that quality control point, the pipe is uncoiled, covered with the yellow jacket, printed and re-coiled. A final leakage inspection is performed just before warehousing or shipping.

The purpose of the following pages is to show the evolution of the technical brochures with time especially regarding the bonding issue.

Note:

To make the reading easier, the quotes from the technical brochures are not given in quotation marks highlighted in blue.Only the title are highlighted in yellow

4.4.1.1. EASYFLEX - Product Name: EASYFLEX®

The manufacturer has been contacted. No information has been provided or collected on the Web. According to another manufacturer, Easyflex does not sell their products in the USA.

4.4.1.2. METAL-FAB INC. - Product Name: DIAMONDBACK®

[*6*: *2001 06 MetalFab Diamondback Specs L1808.pdf*]

The Diamondback shall be installed in accordance with the manufacturer's installation instructions and state or local codes.

[*25*: *2007 03 MetalFab Electrical Bonding and Grounding L2439.pdf*]

In the 2007 Design and Installation Guide, Metal-Fab Inc. requires direct bonding of Diamondback CSST for all gas piping systems incorporating Diamondback CSST, whether or not the connected gas equipment is electrically powered. This requirement is provided as part of the manufacturer's instruction for single-family and multi-family buildings.

Bonding for commercial applications should be designed by engineers knowledgeable in electrical system design and the local electrical code.

Diamondback CSST installed inside or attached to a building or structure shall be electrically continuous and direct bonded to an effective ground-fault current path. The gas piping system shall be considered to be direct bonded when installed in accordance with the following:

• The piping is permanently and directly connected to the electrical service equipment enclosure, the grounded conductor at the electrical service, the grounding electrode conductor (where of sufficient size), or to one or more of the grounding electrodes used.

• A single bond shall be made at or near the service entrance of the structure or the gas meter of each individual housing unit within a multi-family structure.

• The bonding conductor shall be a#6 AWG copper wire.

• Bonding jumpers shall be attached in an approved manner in accordance with *NEC*-2005, 250.70, and the attachment bonding point for the bonding jumper shall be accessible.

• This bond is in addition to any other bonding requirements as specified by local codes.

Diamondback DBC series bonding clamps or equivalent UL 467 listed bonding clamps are recommended.

Bonding clamps for rigid pipe must be of the appropriate size and type.

For attachment to the Diamondback gas piping system, a single bonding clamp must be attached to either a Diamondback brass fitting, a steel manifold, or any rigid pipe component. The bonding clamp and wire are to be installed by a qualified electrician. No location along the corrugated stainless steel tubing portion of the gas piping system shall be used as the bonding attachment point under any circumstances.

The Diamondback Flexible Gas Piping or other gas system components shall not be used as a grounding electrode or as the grounding path for appliances or electrical systems.

As with all Diamondback guidelines, the techniques outlined within this manual are subject to all local fuel gas and building codes.

4.4.1.3. OMEGAFLEX - Product Name: TRACPIPE® / COUNTERSTRIKE®

[*33*: *2004 06 Omegaflex Lightning Safety Recs for GPS 06-2004.pdf*]

Omegaflex has issued a document specific to lightning protection in which the potential hazards are described, as well as Omegaflex's recommendations for increased protection. Omegaflex has developed a CSST product: Counterstrike is considered an effective but affordable tool in increasing the protection of CSST gas piping systems from the damage caused by lightning strikes. The use of this new product, when coupled with improved routing techniques and proper grounding/bonding practices, can considerably improve the resistance of CSST gas piping systems to the lightning strike hazard. The yellow jacket of the traditional CSST TracPipe product has been replaced by a black jacket which is mentioned to have improved energy dissipating properties. The CSST behavior during storms, according to Omegaflex, is related to the capacity of the CSST jacket to withstand electrical charges. Lab tests have been performed by Lightning Technologies Inc. from Pittsfield, MA. According to the results, a traditional CSST with a wall thickness of 0.10 in. is 8 times more resistant than a traditional CSST with a wall thickness of 0.08 in., and the Counterstrike product with a wall thickness of 0.10 in. is 8.25 times more resistant than a traditional CSST with a wall thickness of 0.10 in.

Routing the CSST lower in the buildings or underground in non-metallic conduits is recommended as a measure of safety. Installation underground beneath a slab is considered the best passive protection from lightning.

The recommendations of the manufacturer are:

- Proper grounding of the electrical system per *NEC,* ANSI/NFPA 70

- Proper bonding of the fuel gas system per NFGC NFPA 54/ANSI Z223 to a grounding electrode
- Bonding of all metallic systems and exposed structural steel per *NEC* Section 250.104, especially all metallic supply lines entering the structure
- New technologies such as TracPipe CounterStrike, TracPipe PSII, and GasBreaker
- Lightning protection of the structure against direct lightning strikes per NFPA 780

Four levels of protection are introduced:

- *Baseline* which includes:
    - Bonding of the gas system thru the equipment bond (third wire)
    - An electrical ground electrode with a resistance lower than 25 Ohms to ground
- *Good* (in regions of average lightning strikes history), which adds from the previous level:
    - Equipotential bonding between the fuel gas piping system and the electrical service grounding electrode. The jumper, by the meter location, will be sized accordingly to *NEC* Table 250.66. The bond must be short in distance: the gas meter location should be near the electrical service. Use of braided bonding jumper will be preferred. The bonding should be checked.
    - Bend radius of CSST larger than 8 in. is required
    - Install GasBreaker at meter (optional unless required by local codes)
- *Better* (in regions of above average lightning strikes history), which adds from the previous level:
    - Use increased resistance CSST (CounterStrike) for all gas piping inside
    - Install GasBreaker on all gas branches at the manifold (optional unless required by local codes)

- *Best* (in regions of high lightning strikes history), which adds from the previous level:
    - Install TracPipe PSII underground and under building slab in between meter and manifold

[*26*: *2007 03 Omegaflex TracPipe IG Michigan 03-2007.pdf*]

The 2007 TracPipe Installation Guide mentions that:

- The *National Fuel Gas Code*, NFPA 54/ANSI Z223 states, “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 by NFPA 70, *National Electrical Code* (ANSI/NFPA 70, 1999 Edition).
- The TracPipe gas piping system shall be bonded in accordance with the *National Fuel Gas Code*, NFPA 54/ANSI Z223. The piping system is not to be used as a grounding conductor or electrode for an electrical system.
- For bonding of the TracPipe system, a bonding clamp must be attached to the brass AutoFlare® fitting adapter (adjacent to the pipe thread area – see Figure 4-21) or to a black pipe component (pipe or fitting) located in the same electrically continuous gas piping system as the AutoFlare fitting. The corrugated stainless steel portion of the gas piping system SHALL NOT be used as the bonding attachment point under any circumstances. Bonding electrode conductor sizing shall be in accordance with Article 250 (Table 250-66) of ANSI/NFPA 70. The bonding is a requirement of the *National Electrical Code*.
- Equipotential Bonding of the gas piping system shall be made between the fuel gas piping system and the electrical service grounding electrode using the shortest possible distance. The bonding jumper should be sized in accordance with *NEC* Table 250.66 (based

on the main service conductor size); or in accordance with NFPA 780 Paragraphs 4.14.1.2 thru 4.14.1.4 (main-size lightning conductors) or Tables 4.1.1.1(A) and (B), Class I and Class II wire size. Bonding and grounding connections are to be made by a qualified technician.

- If the building to be piped is in a high lightning flash density area or a region with a high number of thunderstorm days per year, consideration should be given to utilizing the Lightning Risk Assessment method given in Annex L of NFPA 780 to determine the need for a lightning protection system.
- The bonding jumper should be as short as possible. The gas meter should be near the electrical service, if possible. If not, the bond can be connected at any point near the electrical service.
- A braided or stranded bonding jumper should be used.
- Routing of gas piping should be as low in the structure as is reasonably possible for best performance.
- CSST runs should be installed with a bend radius of 8 inches or more whenever possible.
- The use of TracPipe PS-II for use as the trunk line under the building slab from the meter set to the manifold station is recommended. This practice routes the elevated pressure portion of a 2 PSI system completely away from any potential contact with other building metallic systems which can become energized.

[*33*: *2008 08 Omegaflex Lightning Safety Recs for GPS 08-2008.pdf*]

In the 2008 version of the Omegaflex lightning protection brochure, a few changes and additions were made. Failures of components have been modified into damages. Mention of the possibility of causing an explosion has been removed. The second version of the Counterstrike is an effective but affordable tool in increasing the protection of CSST gas piping systems from the damage caused by nearby indirect lightning strikes. The new version of Counterstrike is six times more resistant than the original version. It is not immune to direct lightning strikes. The lab test conditions are specified and are not to duplicate the actual energy conditions generated by lightning strikes. Emphasis is placed on equipotential bonding. The new version of Counterstrike must be bonded in accordance with the current requirements of *NEC*, NFPA70 and of NFGC, NFPA 54 and does not have to comply with the additional requirements imposed by the manufacturers of conventional CSST products.

The recommendations of the manufacturer are:

- Proper grounding of the electrical system per *NEC,* ANSI/NFPA 70
- Proper bonding of the fuel gas system to a grounding electrode per NFGC, NFPA 54/ANSI Z223
- Bonding of all metallic systems and exposed structural steel per *NEC* Section 250.104, especially all metallic supply lines entering the structure
- Use of new technologies such as TracPipe CounterStrike, TracPipe PSII, and GasBreaker
- Lightning protection of the structure against direct lightning strikes per NFPA 780
- Carrying out of a risk assessment in locations subject to high lightning activity per NFPA 780

Routing the CSST lower in the buildings or underground is recommended as a means of improving lightning strike resistance.

[*42*: *2009 06 Omegaflex TracPipe IG 06-2009.pdf*]

In the 2009 TracPipe Installation Guide, Omegaflex emphasizes the fact that TracPipe flexible gas piping *must* be bonded to an effective ground-fault current path. The statement from the 2007 version, “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” has been removed. The bonding of the CSST is a requirement of the *National Electrical Code*. The specification related to sizing the jumper has been removed.

4.4.1.4. PARKER HANNIFIN CORPORATION - Product Name: Parflex®

[*27*: *2007 09 Parker Parflex IG.pdf*]

In the September 2007 Design and Installation Guide, Parker Hannifin Corporation requires that every aboveground portion of the Parflex CSST System be electrically bonded and grounded in accordance with NFPA 70, *NEC,* Article 250. in accordance with this article, a permanent electrical connection to the earth must be made by bonding the CSST to the grounding system through the use of a bonding clamp and wire . This bonding point must be as close to the electrical panel as possible; proximity of the bonding point to the gas meter is also desirable if possible. The wire gauge for bonding must be sized, at a minimum, for the full amperage available through the electrical service (per the *NEC*) and no smaller than a#6 AWG copper wire. Bonding clamps used on the Parflex System must be attached to a Parflex brass fitting (see Figure 1), to a steel manifold (see Figure 2), or to a rigid pipe component connected to a Parflex fitting. The CSST portion of the gas piping system must not be used for the bonding attachment (see Figure 3). CSST also must not be used as a grounding electrode or as the grounding path for appliance or electrical systems. The latest edition of the *National Electrical Code* (*NEC*) should be consulted for additional requirements and specific techniques for equipotential bonding and grounding.

CSST must be routed as far as possible from all conductive materials in the building such as metal ducts, metal water pipes, and electrical wires and cables.

Equipotential bonding consists of making a low impedance electrical connection between the CSST and any adjacent metal structures to create a uniform electrical potential. Adjacent metal systems can include but are not limited to appliances, metal vents, flues, electrical wires, and metal pipes. Bonding and grounding of all electrically conductive metal systems and metallic structural material is recommended.

In order to further increase protection of an entire building structure from potential lightning damage, the installer and user—particularly those in geographical areas prone to lightning strikes—should consider the installation of a lightning protection system pursuant to NFPA 780 or other recognized standard.

[*152*: *100929 Parker Parflex Hannifin.pdf*]

The Parker Parflex Division sold their entire product line to OmegaFlex about three years ago.

4.4.1.5. TITEFLEX - GASTITE®

[*98*: *Gastite CSST 2.pdf*]

The Gastite CSST complies with ANSI LC1 “Fuel Gas Piping Systems Using CSST.” Manufacturing materials are: ASTM A240 Type 300 corrugated stainless steel tubing with a minimum wall thickness of .010" and jacketing of UV resistant polyethylene meeting the requirements of ASTM E84 for flame spread and smoke density. The tubing melting point is 2400°F. The jacket melting point is 350°F.

[*8*: *2001 TrainingGuide.pdf*]

In the 2001 Gastite training guide, bonding and grounding of CSST are not mentioned. As far as grounding is concerned, however, it is stated that "Gastite flexible gas piping must never be used as a grounding electrode or as the grounding path for appliances or the electrical systems. Refer to local codes for other approved grounding points. In the absence of local codes, refer to *National Fuel Gas Code*, NFPA-54 and *National Electrical Code,* NFPA-70."

[*9*: *2003 09 Code Acceptance.pdf*]

The Gastite CSST is manufactured according to ANSI LC1. Its installation must follow the same standards. The CSST is considered acceptable by the following codes:

- National Fuel Gas Code – NFPA 54 – 2002 edition
- Liquefied Petroleum Gas Code – NFPA 58 – 1998 edition
- International Fuel Gas Code – 2003 edition
- Uniform Plumbing Code – 2003 edition

[*11*: *2004 04 GastiteSpec15195.pdf*]

Grounding and bonding are not mentioned in the Part 3 of the 2004 product specifications, which describes how the product will be installed at the construction site.

[*18*: *2006 08 Gastite Electrical Bonding and Grounding 08-2006.pdf*]

A bulletin was issued in August 2006 which specified the bonding and grounding requirements for CSST: In accordance with NFPA 70, *National Electrical Code* (*NEC*), proper bonding and grounding of gas piping systems in a structure and the structure's electrical system by a qualified electrician is required in order to provide an effective continuous path to conduct stray voltage/current safely to ground. The *NEC* considers the bonding of all metallic systems and objects as being good practice. Gastite thus requires the bonding to be made to the electrical earth grounding system of the structure through the use of a bonding clamp and wire in accordance with the *NEC*. The bonding point must be as close to the electrical panel and to the gas meter as is practical. The wire gauge must be sized, at a minimum, for the full amperage available through the electrical service. Bonding clamps must not be attached directly to the CSST. The bulletin also refers to NFPA 54 bonding requirements for a continuous, permanent, low impedance effective fault current path. It clearly states that if the systems are not properly bonded, the difference in potential between the systems may cause the charge to arc to another system. Arcing can cause damage to CSST. Bonding and grounding as set forth above will reduce the risk of arcing and related damage. Depending upon the conditions specific to the structure's geographical location, the owner should consider whether a lightning protection system is necessary or appropriate. The lightning protection systems are covered by NFPA 780, the Standard for ILPS, and other standards. A figure of bonding of a CSST fitting is provided in the bulletin.

[*22*: *2006 Installation Guide Gastite.pdf*]

In the November 2006 version of the Design and Installation Guide, the tracer is not mentioned in its underground installations section. The content of the August 2006 bulletin has been included in Section 4.10, Electrical Bonding/Grounding.

[*24*: *2007 01 TB2007_01.pdf*]

In January 2007, Gastite issued a revised bulletin requiring direct bonding of CSST. This requirement is part of the manufacturer's instruction for single-family and multi-family buildings. For commercial buildings, bonding should be designed by engineers knowledgeable in electrical system design and the local electric code. Direct bonding is defined as a situation in which the piping is permanently and directly connected to:

- the electrical service equipment enclosure
- the grounded conductor at the electrical service
- the grounding electrode conductor (where of sufficient size)
- or, to one or more of the grounding electrodes used

A single bonding point must be made at or near the service entrance of the structure or the gas meter of each individual housing unit within a multi-family structure. The bonding wire should be a#6 AWG copper wire. Bonding jumpers should comply with *NEC*-2005, Article 250.70, such as those listed to UL 467. The CSST tubing portion of the system shall not be used as the point of attachment of the bonding conductor. Figures of bonding of a manifold and bonding of a black pipe are added to that installation guide.

[*28*: *2007 Gastite 2009 NFGC.pdf*]

In October 2007, a proposal before the *National Fuel Gas Code* (NFGC) Committee to modify Section 7.13 (Bonding and Grounding) and to require the bonding of CSST systems directly to the grounding electrode system rather than using the equipment grounding conductor as the bonding means was discussed. The following modifications were approved and incorporated in the 2009 NFGC:

> 7.13.1 Pipe and Tubing Other Than CSST: Each aboveground portion of a gas piping system other than 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 when it is connected to appliances that are connected to the appliance grounding conductor of the circuit supplying that appliance.
>
> 7.13.2 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.
>
> 7.13.3 Gas piping shall not be used as a grounding conductor or electrode. This does not preclude the bonding of metallic piping to the grounding electrode system.

These new requirements corresponded with the manufacturer's requirements.

[*29*: *2007 Gastite_Installation_Instructions.pdf*]

The January 2007 version of the Gastite Design and Installation Guide includes the modifications mentioned in the previous January 2007 bulletin.

[*38*: *2008 11 Gastite_LightningSafety_HomeOwner.pdf*]

In November 2008, Gastite edited a leaflet dedicated to lightning safety for homeowners. It will be introduced in the next Design and Installation Guides.

Important Gastite Lightning Safety Warning

Your home and your family.

Lightning is a highly destructive force—and nothing's more important than ensuring lightning safety in America's homes. At Gastite, we require direct bonding, an important safety enhancement, for our Corrugated Stainless Steel Tubing (CSST) gas piping—and have additional installation requirements to help further ensure safety.

In fact, all metallic systems within a home (for example, your electrical, plumbing and heating and air conditioning systems) can be affected by lightning strikes. Safety isn't just about how each system is installed—it's also about how each installation relates to other home metallic systems. To help maximize safety, your builder or remodeler and your local building inspector had the responsibility to ensure proper installation of every metallic system per local codes and requirements.

Should you have any concerns about whether Gastite CSST—or any other metallic building systems components—were properly installed per safety requirements, we recommend that you have them inspected by a qualified heating and air conditioning and/or electrical contractor.

Gastite Lightning Safety Warning

1 PROPERLY BONDING and grounding the Corrugated Stainless Steel Tubing (CSST)system may reduce the risk of damage and fire from a lightning strike. Lightning is a highly destructive force. Even a nearby lightning strike that does not strike a structure directly can cause systems in the structure to become electrically energized. Differences in potential between systems may cause the charge to arc between systems. Such arcing can cause damage to CSST, including holes. Bonding and grounding should reduce the risk of arcing and related damage. The building owner should confirm that a qualified contractor has properly bonded the CSST gas system to the grounding electrode system of the premises. Refer to Section 4.10 Electrical Bonding/Grounding in the Gastite Design & Installation Guide for details on bonding & grounding CSST.

2 ALL OWNERS should consult a lightning safety consultant to determine whether installation of a lightning protection system would be required to achieve sufficient protection for all building components from lightning. Factors to consider include whether the area is prone to lightning. Areas with high lightning risk include but are not limited to: Alabama, Arkansas, Florida, Georgia, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maryland, Michigan, Mississippi, Missouri, New Mexico, North Carolina, Ohio, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Virginia and West Virginia. One currently available source of information regarding areas more prone to lighting than others is the flash density map provided by the National Weather Service which can be found at http://www.lightningsafety.noaa.gov/lightning_map.htm. Lightning protection systems are beyond the scope of this manual and installation guidelines, but are covered by National Fire Protection Association, NFPA 780, the Standard for the Installation of Lightning Protection Systems, and other standards.

3 THE OWNER should confirm with the local gas supply utility company that a suitable dielectric union is installed at the service entry of the structure between underground metallic piping and the gas pipes going into the building as required by code.

4 NATIONAL ELECTRIC CODE (NEC),Section 250.104b, states that "bonding all piping and metal air ducts within the premises will provide additional safety". Gastite recommends that all continuous metallic systems be bonded and grounded. The owner should confirm with an electrical or construction specialist that each continuous metallic system in a structure has been bonded and grounded by an electrical professional in accordance with local building codes. This should include, but is not limited to metallic chimney liners, metallic appliance vents, metallic ducting and piping, electrical cables, and structural steel.

5 CARE SHOULD BE TAKEN when installing any type of fuel gas piping (including CSST, iron, or copper) to maintain as much separation as reasonably possible from other electrically conductive systems in the building. Refer to sec. 4.3 Routing, in the Gastite D&I Guide for installation techniques. Consult local building codes as to required separations for CSST from such conductive systems including metallic chimney liners, metallic appliance vents, metallic ducting and piping, and electrical cables. See for instance the Indiana Residential Code, section 675 IAC 14-4.3-155.5 Section G2411.1;gas pipe bonding.

6 LOCAL BUILDING CODES are controlling, however, as a general practice, fuel gas piping, including CSST, should not be installed within a chase or enclosure that houses a metallic chimney liner or appliance vent that protrudes through the roof. In the event such an installation is necessary and conforms to local building codes, the metallic chimney liner or vent must be bonded and grounded by a qualified electrical professional, and a separation distance, as specifically permitted by the applicable local building code between the CSST and the metallic chimney liner or vent, is required. Physical contact between CSST and the metallic chimney liner and/or vent is prohibited. If this physical separation cannot be specifically identified in the local building code and achieved or any local building code requirements cannot be met along the entire length, then rerouting of the CSST is required unless such installation is specifically permitted by the local building inspector.

Gastite Lightning Safety Home-Owner bulletin

[*39*: *2008 Gastite_Installation_Instructions.pdf*]

The November 2008 version of the Gastite Design and Installation Guide introduced modifications. For commercial structures the required engineer is replaced by a knowledgeable person. The effective ground-fault current path is replaced by the electrical ground system of the premise. The single bond made at or near the service entrance of the structure or the gas meter of each individual housing unit within a multi-family structure is replaced by a single bond connection which shall be made downstream of the individual gas meter for each housing unit and upstream of any CSST connection. The bonding/grounding clamp must create a metal-to-metal contact with the piping. The CSST bonding clamp will be attached to either a segment of steel pipe or to a rigid pipe component. Figures of bonding of CSST fitting and manifold are removed. The document warns about the risk related to the indirect lightning strikes.

[*37*: *2008 11 Gastite Routing TB2008_02.pdf*]

In November 2008, the concept of separation distance was partially introduced, as well as specific requirements for CSST pipe supports and CSST pipe routing.

[*134*: *The wholesaler - March 2009.pdf*]

The codes which are of particular importance for CSST are:

- *National Electrical Code,* Section 250.104b, states that "bonding all piping and metal air ducts within the premises will provide additional safety." Gastite recommends that all continuous metallic systems be directly bonded and grounded. The owner should confirm with an electrical or construction specialist that each continuous metallic system in a structure has been bonded and grounded by an electrical professional in accordance with local building codes. This should include, but is not limited to directly bonding metallic chimney liners, metallic appliance vents, metallic ducting and piping, electrical cables, and structural steel.

- The 2009 edition of NFPA 54, *National Fuel Gas Code* requires CSST gas piping systems to be directly bonded to the electrical service grounding electrode system.
- Local building codes dictate that as a general practice, fuel gas piping, including CSST, should not be installed within a chase or enclosure that houses a metallic chimney liner or appliance vent that protrudes through the roof. In the event that such an installation is necessary and conforms to local building codes, the metallic chimney liner or vent must be bonded and grounded by a qualified electrical professional, and a separation distance between the CSST and the metallic chimney liner or vent —a distance specifically permitted by the applicable local building code— is required. Physical contact between CSST and the metallic chimney liner and/or vent is prohibited. If this physical separation cannot be specifically identified in the local building code and achieved, or any local building code requirements cannot be met along the entire length, then rerouting of the CSST is required unless such an installation is specifically permitted by the local building inspector. The building owner should confirm that a qualified contractor has properly bonded the CSST gas system to the grounding electrode system of the premises. Refer to Section 4.10, Electrical Bonding/ Grounding, in the Gastite Design and Installation Guide for details on bonding and grounding CSST.

Installers should also take into account guidance provided by the following regulatory organizations:

- *National Fuel Gas Code*, NFPA 54/ANSI Z223.1 /
- National Standard of Canada
- Natural Gas and Propane Installation Code, CSA-B149.1
- Uniform Plumbing Code
- The International Code Series

- The Federal Manufactured Home Construction and Safety Standards, 24 CFR Part 3280
- The Manufactured Housing Construction and Safety Standards, ICC/ANSI 2.0, or NFPA 501, *Standard on Manufactured Housing*.

Consideration must also be given to installation of a lightning protection system pursuant to NFPA 780

[*54*: *2010 06 TB2010-01.pdf*]

In June 2010, the possibility of attaching a single bonding clamp to the Gastite brass hex fitting was introduced. A figure was added. Erico clamps must be used.

[*55*: *2010 08 D+I_Guide_August2010.pdf*]

In August 2010, the new product FlashShield is introduced which does not require additional bonding, at minimum, than what is specified in *National Electrical Code* Section 250.104 for rigid metal piping.

4.4.1.6. TRU-FLEX - Product Name: Pro-Flex®

[*23*: *2006 Tru-Flex-Bulletin.pdf*]

A bulletin was issued in November 2006 which specified the bonding and grounding requirements for CSST: In accordance with NFPA 70, *National Electrical Code* (*NEC*), proper bonding and grounding of gas piping systems in a structure and the structure's electrical system by a qualified electrician is required in order to provide an effective continuous path to conduct stray voltage/current safely to ground. The *NEC* considers the bonding of all metallic systems and objects as being good practice. Tru-Flex Metal Hose Corp. thus requires the bonding to be made to the electrical earth grounding system of the structure through the use of a bonding clamp and wire in accordance with the *NEC*. The bonding point must be as close to the electrical panel and to the gas meter as practical. The wire gauge must be sized, at a minimum, for the full amperage available through the electrical service. Bonding clamps must not be attached directly to the CSST. Tables are provided in ANSI/NFPA 70 for sizing the bonding connectors. The bulletin also refers to NFPA 54 bonding requirements for a continuous, permanent, low impedance effective ground-fault current path. The bulletin clearly states that if the systems are not properly bonded, the difference in potential between the systems may cause the charge to arc to another system. Arcing can cause damage to CSST. Bonding and grounding as set forth above will reduce the risk of arcing and related damage. Depending upon the conditions specific to the structure geographical location, the owner should consider whether a lightning protection system is necessary or appropriate. The lightning protection systems are covered by NFPA 780, the Standard for ILPS, and other standards. A figure of bonding of a CSST fitting is provided in the bulletin.

[*32*: *2008 07 Pro-Flex_install.pdf*] and [*40*: *2008 TruFlex Electrical-17648.pdf*]

In July 2008, Tru-Flex Metal Hose Corp. issued a technical bulletin and an Installation/Training Guide which require a direct bonding of CSST for single-family and multi-family buildings. For commercial buildings, bonding should be designed by qualified persons knowledgeable in electrical system design and the local electric code. Direct bonding is defined in the bulletin with the following terms:

• A bonding jumper is permanently and directly connected to the electrical service grounding system. This can be achieved through a connection to the electrical service equipment enclosure, the grounded conductor at the electrical service, the grounding electrode conductor (where of sufficient size) or to the one or more grounding electrodes used.

• A single bond connection is made to the building gas piping downstream of the utility meter or second stage regulator (LP systems), but near the gas service entrance of the structure, or downstream of the gas meter of each individual housing unit within a multi-family structure. (A bonding connection shall not be made to the underground, natural gas utility service line or the underground supply line from a LP storage tank).

• The bonding conductor shall be no smaller than a#6 AWG copper wire or equivalent. Bonding/grounding clamps shall be attached in an approved manner in accordance with *NEC* and the listing of the clamp. Bonding/grounding clamps shall be listed to UL 467. The point of attachment for the bonding conductor shall be accessible. This bond is in addition to any other bonding requirements as specified by local codes.

• For attachment to the CSST gas piping system, a single bonding clamp must be attached to either a Pro-Flex® brass fitting, to a steel manifold, or to any rigid pipe between the meter and the first CSST fitting in the system. The corrugated stainless steel tubing portion of the gas piping system shall not be used as the point of attachment of the bonding conductor at any location along its length under any circumstances.

A warning is issued related to indirect lightning strikes effects.

[*46*: *2009 09 17482_TF_TrainingG15.pdf*]

CSST through metal framing: When using the CSST thru metal enclosures, the CSST tubing must be protected by grommets, bushing or armor (Floppy-Flex™), PVC tape, tube shrink sleeve material, or a minimum of four wraps of #10 Mil Duct-Tape. This is to ensure that no physical contact will be made between the metal and the CSST tubing that would cause mechanical wear.

[*153*: *2009 09 TruFlex Electrical-17479.pdf*]

The bonding requirements are made retroactive. Paint must be removed from surface beneath clamp location.

4.4.1.7. WARD MANUFACTURING COMPANY - Product Name: Wardflex®

[*15*: *2006 01 Wardflex IG 01-2006.pdf*] *and* [*20*: *2006 11 Wardflex Electrical Bonding and Grounding 16.pdf*]

In the 2006 Technical Bulletin #16 and Wardflex Design and Installation Guide, Ward Manufacturing requests that in accordance with the *National Electrical Code* (*NEC*), proper bonding and grounding of gas piping systems in a structure and of the structure's electrical system by a qualified electrician is required. Ward Manufacturing requires the gas piping system to be bonded to the electrical earth grounding system of the structure through the use of a bonding clamp and wire. The bonding point must be as close to the electrical panel as practical; proximity of the bonding point to the gas meter is also desirable. The wire gauge for this bond must be sized, at a minimum, for the full amperage available through the electric service. Further minimizing impedance over the bonding assembly is desirable.

The *NEC* should be referenced for additional requirements and specific techniques for bonding and grounding.

For attachment to the WARDFLEX gas piping system, bonding clamps must be attached to the WARDFLEX brass fitting, a steel manifold, or to a rigid pipe component connected to a WARDFLEX fitting. The corrugated stainless steel portion of the gas piping system must not be used as the bonding attachment point under any circumstances. For sizing bonding connectors, refer to ANSI/NFPA 70, Table 250.66.

Bonding and grounding requirements are also addressed in the *National Fuel Gas Code*, ANSI/NFPA 54, which specifically requires: "…each above ground portion of a gas piping system which is likely to become energized shall be electrically continuous and bonded to a designed, permanent, low impedance effective ground fault current path."

The user should consider installation of a lightning protection system per NFPA 780 and other standards, particularly in areas prone to lightning.

[*17*: *2006 03 ASTM_E-84_ComplianceReport.pdf*]

A test report for surface burning characteristics performed in 2006 revealed a Flame Spread Index of 10 and a Smoke Index of 25 for the Wardflex CSST.

[*35*: *2008 09 Technical_Bulletin_WF2008.pdf*]

In Technical Bulletin # WF2008-1, Ward Manufacturing requires direct bonding which is considered to be done when the CSST is installed in accordance with the following instructions:

- A bonding jumper is permanently and directly connected to the electrical service grounding system. This can be achieved through a connection to the electrical service equipment enclosure, the grounded conductor at the electrical service, the grounding electrode conductor (where of sufficient size) or to one or more grounding electrodes used.

- A single bond connection is made to the building gas piping downstream of the utility meter or second stage regulator (LP systems) but near the gas service entrance (either outdoors or indoors) of the structure, or downstream of the gas meter of each individual housing unit within a multi-family structure. A "daisy chain" configuration of the bonding conductor is permitted for multi-meter installations. A bonding connection shall not be made to the underground, natural gas utility service line or the underground supply line from a LP storage tank.

- The bonding conductor is not smaller than a #6 AWG copper wire or equivalent. The bonding conductor is installed and protected in accordance with the *NEC*.

- The bonding conductor is attached in an approved manner in accordance with *NEC,* and the point of attachment for the bonding conductor is accessible.

- Bonding/grounding clamp used is listed to UL 467 or other acceptable national standards.

- The bonding clamp is attached at one point within the piping system to a segment of rigid pipe or a pipe component such as a nipple, fitting, or manifold, provided it is manufactured with an appropriate and code listed material. The bonding clamp must be attached such that metal-to-metal contact is achieved with the steel pipe component. Any paint or applied coating on the pipe surface beneath the clamp should be removed. Figures are provided for guidance. The corrugated stainless steel tubing portion of the gas piping system shall not be used as the point of attachment of the bonding clamp at any location along its length.

[*43*: *2009 06 WARDFLEX_D&I_GUIDE_Eng.pdf*] and [*44*: *2009 06 WARDFLEX_D&I_GUIDE_ FR_lo.pdf*]

Technical Bulletin # WF2008-1 is included in the 2009 version of the Wardflex Design and Installation Guide.

[*50*: *2009 10 Spanish_WF_Bonding_Tech2008_ES.pdf*]

Technical Bulletin # WF2008-1 has been translated into Spanish.

4.4.2. National codes and standards

4.4.2.1. ANSI-LC1

The first standard we have to consider is ANSI-LC 1-2005/CSA6-26-2005, as it is directly related to CSST.

The table of contents of this standard doesn't show any tests related to lightning or electrical current withstand:

The only related item appears in Exhibit D, Minimum Design and Installation Manual Requirements: "4.10 Electrical Bonding/Grounding."

This means that each manufacturer should provide its own requirements regarding bonding and grounding.

4.4.2.2. NFPA 54

Then we have to consider NFPA 54. It is interesting to consider not only the present wording of NFPA 54, but also the history of the current version and how the bonding request was supported.

In the ROP for the 2005 revision of NFPA 54, we find a first proposal to include CSST specifically as one of the possible tubing forms.

54-36 Log# CP127 NFG-AAA **Final Action: Accept**
(3.3.205)

Submitter : Technical Committee on National Fuel Gas Code
Recommendation: 3.3.205 Tubing. Semirigid conduit of copper, steel, aluminum, CSST or plastic.
Substantiation: The clarify that CSST is included under the definition for tubing.
Committee Meeting Action: Accept
Number Eligible to Vote: 30
Ballot Results: Affirmative: 25
Ballot Not Returned: 5 BRUNO, BUCHAL, CAVE, DOUCETTE, GILBERT

There is also reference to the ANSI LC 1 standard and to manufacturer instructions. There is a proposal to avoid mechanical damage to CSST in appliances. Apparently this is not related to our study, as damages on CSST related to lightning seem not to be located at appliances.

The ROP for the 2008 revision of NFPA 54 contains proposals that specifically address the subject of our study, since this is the first introduction of the request to bond CSST: “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.”

The provided substantiation looks as follows:

Substantiation: Gas piping systems installed inside buildings have demonstrated a propensity to become energized from nearby lightning strikes. Conventional bonding of gas piping through the equipment grounding conductor (NFGC 7.13.1 and NEC 250.104(B)) has proven inadequate (in these circumstances) to prevent arcing between the gas piping and other nearby electrically conductive systems. The attached technical article describes (in detail) the arcing damage inflicted on gas piping caused by indirect lightning strikes. CSST manufacturers collectively report dozens of damaged systems caused by improper or inadequate bonding resulting in fire damage or loss of property. Therefore, modifications are proposed to Section 7.13 to allow alternative methods for direct bonding of gas piping to the grounding system to insure a minimum threshold of protection from all threats (including indirect lightning strikes) that are likely to energize the piping. Current bonding of gas piping to the equipment grounding conductor will continue to be permitted. Similar language has been submitted to the NEC (National Electrical Code) for the 2008 cycle.

And the final text approved is:

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.

The ROC for this 2008 version shows that there was debate regarding the need for bonding.

For example, there was a request to bond all pipes and not only CSST. Evidence exists apparently of damages on other pipes (such as copper, steel, and the like). This request was rejected due to the fact that only the bonding of CSST was included in manufacturers' instructions.

NPGA at the time of the ROC stated no firm position on the effectiveness of using of 6 AWG wire for bonding:

> At this time, NPGA has no formal position regarding the effectiveness or the need for a #6 AWG copper wire for bonding to the grounding electrode system. The NPGA TSS Committee task force on CSST neither endorses nor disputes the effectiveness of using a #6 AWG copper wire to mitigate lightning hazards.

The Technical Committee on Lightning Protection submitted a comment to clarify that in a case where a lightning protection system is installed, the gas piping does need to be bonded to the LPS grounding system along with all other metallic parts entering the structure. This does not conflict with the *NEC* requirement that the gas piping cannot be used as a ground electrode.

Justification report of the need for 6 AWG has been provided at this stage by CSST manufacturers.

4.4.2.3. NFPA 70

As already described in the ROC of 2008 version of NFPA 54, there is a need to have similar requirements in NFPA 70.

In the ROP of 2010 for NFPA 70 we find a request to bond CSST even if it is slightly different from the NFPA 54 version:

(2) CSST. Corrugated stainless steel tubing gas piping systems shall be bonded by connection to a metallic piping segment or fitting, either outside or inside the building, between the individual gas meter and the first CSST fitting. The bonding jumper shall be sized in accordance with Table 250.66 based on the size of the service-entrance conductor or feeder supplying each occupancy and as permitted in 250.66(A), (B) and (C) but not smaller than 6 AWG copper (or equivalent).

This proposal was rejected for the following reason:

Panel Statement: CMP-5 is not convinced that bonding to or around portions of CSST will solve the problem. No test records were provided to substantiate the adequacy of the minimum 6 AWG conductor. The problem could be directly related to the design and wall thickness of CSST. CMP 5 was made aware of at least one manufacturer's product that does not require bonding beyond the requirements of Section 250.104 contrary to the information provided in the substantiation. The mitigation of the effects of lightning is a design option. The purpose of the NEC is the practical safeguarding of persons and property from hazards arising from the use of electricity. The recommendation is not currently prohibited by the NEC and should be covered by product standards. NFPA 54 contains bonding requirements specific to this product, and those requirements do not conflict with the NEC requirements in Section 250.104(B).

Even if the justification of the #6 AWG is in question, the main reason to refuse this request is that it doesn't fit with the scope of the *Code*.

And in the ROC of the 2010 version of NFPA 70, it is stated in one of the comments:

Substantiation: Corrugated Stainless Steel Tubing (CSST) gas piping systems would be an added burden to the Authority Having Jurisdiction and by an electrician or electrical industry as their was in the past class action litigation taken against this product.

This is a fuel gas issue concerning "passive lightning protection" and not addressed by the National Electrical Code as stated in 90.1(A) "the use of electricity" and 90.2(A)(3) "and equipment that connect to the supply of electricity" and 250.104(B) "The equipment grounding conductor for the circuit that is likely to energize the piping shall be permitted to serve as the bonding means."

The National Electrical Code would not prohibit this gas piping method from being bonded to the intersystem bonding required by section 250.94 CSST may need to have internal design changes or other incorporated engineering corrections when there is a national problem with lightning and not the use concerns with electricity and the scope of the National Electrical Code to correct this product dilemma.

However, another comment states that it is the electrician's task to make the bond, and if this doesn't appear in the *NEC* nobody can certify that the bond will be made, even if NFPA 54 requires it.

4.4.2.4. NFPA 780

We are referring here to the 2008 edition of NFPA 780 to be consistent with discussions related to NFPA 54.

4.14.1: All grounding media and buried metallic conductors that can assist in providing a path for lightning currents in or on a structure shall be interconnected to provide a common ground potential.

4.14.1.2: Underground metallic piping shall include water service … gas piping … underground liquefied petroleum gas piping. …

4.14.1.3: Interconnection to a gas line shall be made on the customer's side of the meter.

4.14.1.4: Main size lightning conductors shall be used for interconnecting these grounding systems to the lightning protection system.

4.4.3. Installation practices

The following pictures come from the Web, from private pictures, or from various published sources.

CSST is run Outside a Metal Tube for a Short Distance

This installation doesn't seem to be a general practice. This is an installation in Indiana. Upon inspection the gas company said that by Indiana code, the CAT5 cables must be greater than 2" away from all yellow CSST gas line. The interface between metal tubing and CSST is probably at high risk. A manufacturer pointed out that the bend radius was smaller than the minimum bend radius which was specified in the manufacturer's installation instructions.

Bonding of Gas Pipe at Building Entrance

Note the size of the bonding conductor is bigger than#6 AWG, due to the fact that there is a lightning protection system installed per NFPA 780. It is interesting to note that in a few cases for which we have detailed description of installation, the bonding is made at the manifold only (sometimes in the attic), and not directly at the service entrance as shown in this figure and also as requested by the code.

Grounded CSST Piping at Manifold

The CSST piping shown here is at the manifold with grounding provided by the CSST installer (small solid #6 AWG conductor) and the bond to the Lightning Protection System (main-sized conductor). Note that in this case the CCST bonding shown in the picture at the manifold in the attic is additional to the bonding at the entrance of the installation as required by NFPA 54.

This is an installation in Florida where the gas piping enters the attic in rigid (steel) piping and transitions to CSST which feeds the manifold (on the left), located in the attic space. The smaller grounding conductor is run to the grounding electrode for the electrical service entry.

Rigid pipe is not visible, but is located about 9 meters away in a direct line to the bottom left of the picture. Once the rigid pipe enters the structure, there is a 90 degree elbow and the CSST pipe is connected using the same type of connection as is seen at the manifold. In these installations, the manifold is most often located in the attic above the garage where it is easiest to get to. By locating the manifold at the access point to the attic, the shutoff valve is easily accessible. In other installations, the rigid pipe does run directly to the manifold. In one other cases (in North and South Carolina, for instance), this rigid pipe would be tapped off with a CSST run on the supply side of the manifold in a crawl space under the house.

Note that the installation depicted in the picture doesn't exist any longer, as the CSST has been replaced by the owner by black pipe.

ERITECH® brand of CWP grounding clamps are listed for connecting HEX Fittings on CSST systems.

ERICO® has developed a range of CWP Grounding Clamps which help minimize the possibility of damage from a lightning strike or other transient voltage by reducing the electrical potential between metallic objects and building systems.

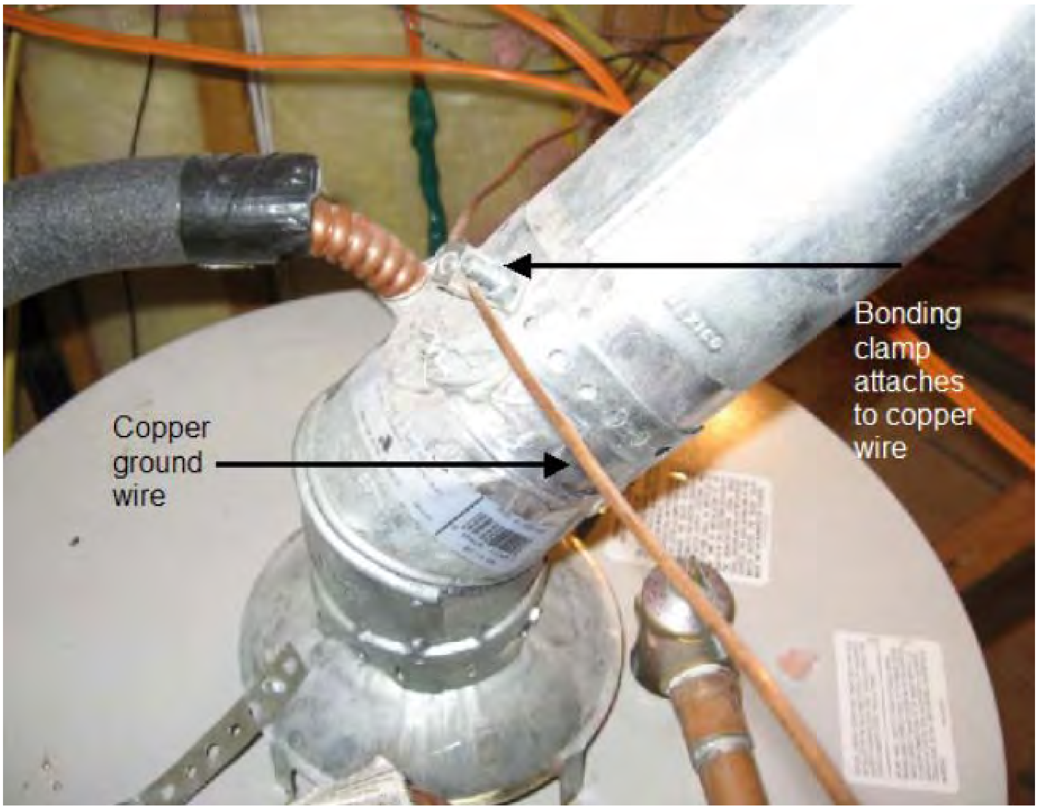
The clamps, which are part of the ERITECH® line of Facility Electrical Protection products, conform to the requirements of the 2009 edition of NFPA® 54, NFGC® (National Fuel Gas Code) and NEC® (National Electric Code) for bonding corrugated stainless steel tubing (CSST) gas piping systems to the grounding conductor of the building's electrical system.

CWP Grounding Clamps are ideal for connecting brass hex fittings on flexible gas piping, copper grounding conductors, galvanized water pipes, copper water tubing or ground rods ranging from 1/2" to 4" to a ground conductor to bond all ground points together. This helps eliminate ground loops and creates an equipotential plane.

Made of a high-strength silicone bronze, the clamps are ideal for use in applications, such as lightning protection, fault current ground, signal reference grid and static ground. They are UL® Listed (ANSI®/UL 467 Category KDER).

Bronze ground pipe clamp for bare wire, for making connection between copper grounding conductor, galvanized water pipe, copper water tubing, copper ground rod or brass hex fittings, Sizes 1/2" through 4", Cat. Nos. CWP-1J, -2J, -3J.

Data Sheet for ERICO CSST Bonding Clamp and UL Listing

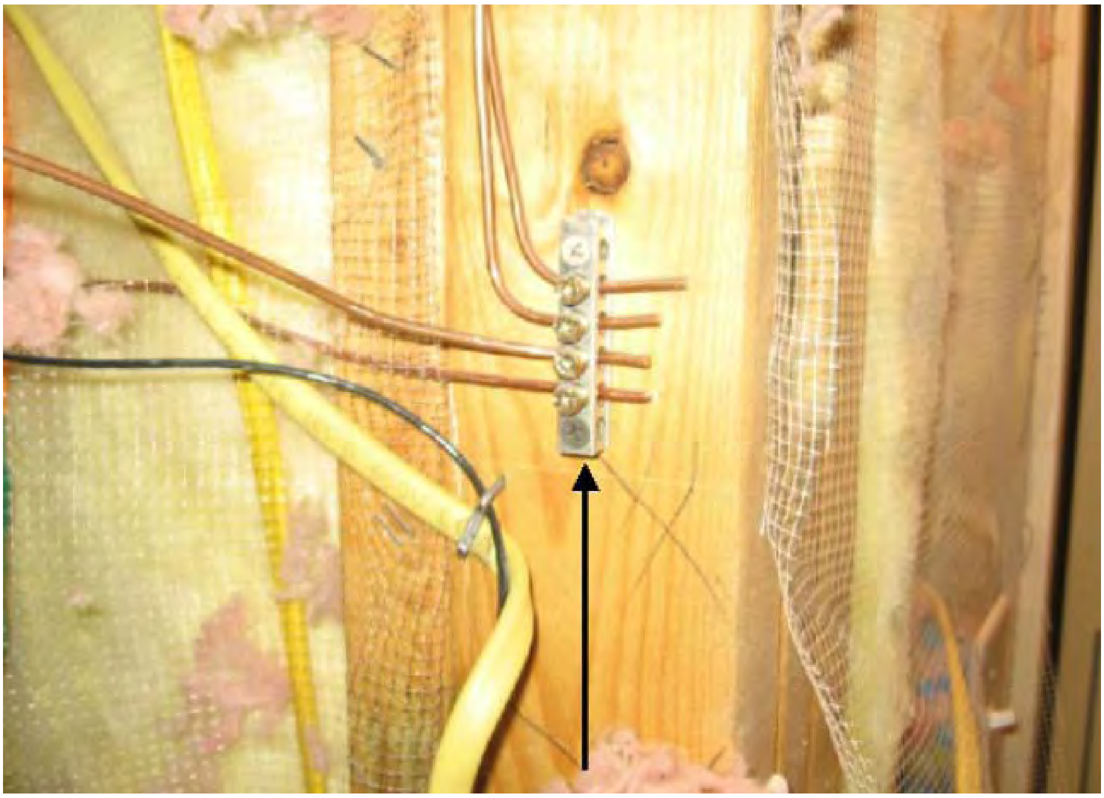


Bonding of a Water Heater

View of the Metal Flue Pipes on a Roof

The metal flue pipes shown in this photo may act as the preliminary lightning attachment point in the case of lightning strike on the roof; thus, significant lightning current may be flowing through CSST.

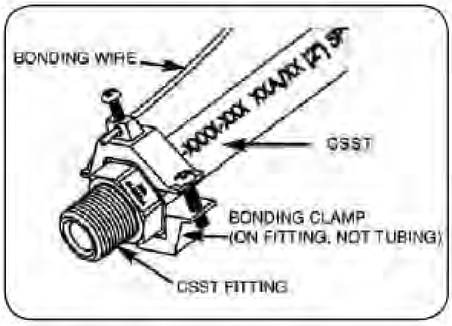
Attic CSST Installation without Visible Bonding



Equipotential Bonding for Various Metallic Items in a House

- **CSST bond wires or clamps shall NEVER be connected to:**
  - Company natural gas facilities.
  - A ground independent of the electrical service grounding system.
    NOTE: If the systems are not bonded properly, the difference in potential can cause an arc which may damage CSST.
  - The corrugated stainless steel portion of the pipe (clamps must be attached to the brass fitting, steel manifold, or other rigid customer-owned pipe).

- **CSST bond wires or clamps shall ALWAYS be connected to:**
  - Customer piping as close to the natural gas meter as practical.
  - The CSST brass fitting, a customer-owned steel manifold, or a customer-owned rigid pipe component connected to a CSST fitting.
  - The electrical service grounding system. This connection may be made at either the ground rod, on the ground wire running to the rod, or in the electric service panel.

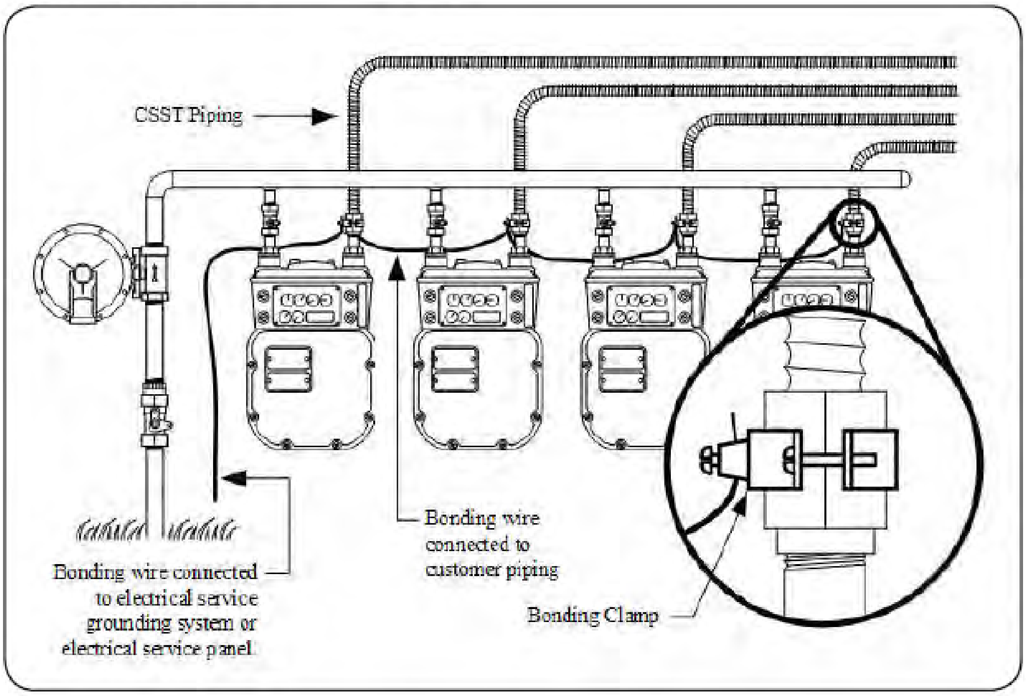


Bonding CSST does not prevent damage from a direct lightning strike. It is intended to direct voltage/current from nearby lightning strikes safely to the ground.

Bonding Dos and Don'ts

Acceptable CSST installations

Acceptable CSST installation - example 1



Acceptable CSST installation - example 2

Bonding Recommendations at the Meter

4.5. Relevant Technical Data on the mechanisms of lighting energy transfer which can cause damage to CSST, including direct and indirect strikes and ground potential rise, influence of other metal components, influence of other energy sources, etc.

The first damage that needs to be considered is effect of direct lightning impact on metal sheets. A paper from GE [*101*: *GE paper Effect of lightning on thin metal surfaces.pdf*] clearly explains that damages are more a consequence of the charge than of the magnitude of the current (continuing current of lightning instead of first impulse). The figure below gives the size of the holes for various values of current charge for a 15 mm galvanized iron sheet. CSST is thinner than this (less than 10 mm).

It is likely that any direct impact is not the cause of damage in the CSST incidents, but partial lightning might be. It is clear that, based on results from GE on thicker metal plates, even with relatively low values of charge associated with partial lightning currents, holes may be created on a thin sheet of steel.

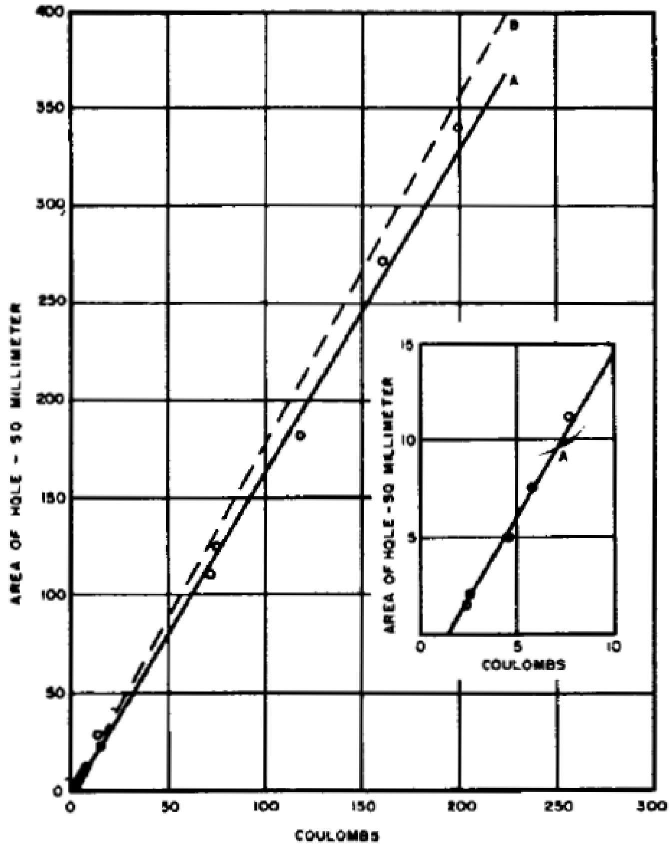


Figure 5. Relation between coulombs in the arc and resultant area of holes burned in (*A*) 15-mil galvanized iron sheets, (*B*) 20-mil copper sheets

Impact on Metal Sheets (see [101])

The following formulas are provided:

$$C = \frac{A}{25} \times t^{0.9} \quad (t = 0 \text{ to } 35 \text{ mils})$$

$$C = \frac{A}{245} \times t^{1.54} \quad (t = 35 \text{ to } 150 \text{ mils})$$

C = coulombs
A = area of hole in square millimeters
t = thickness of sheet in mils

Charge Formulas (see [101])

Furthermore, stainless steel leads to a higher temperature rise than the galvanized steel presented above in GE paper. The following table from IEC 62305-3 gives the temperature rise for conductors of different sized sections as a function of *W/R* (the specific energy - the charge is represented by the surface under the curve of the current versus time, whereas the specific energy is represented by the surface of the square of the current versus time; the charge is related to the arc voltage, whereas the specific energy is related to the Joule effect heating in the resistor).

Cross-section mm²	Material											
	Aluminium			Mild steel			Copper			Stainless steel*		
	W/R MJ/Ω			*W/R* MJ/Ω			*W/R* MJ/Ω			*W/R* MJ/Ω		
	2,5	**5,6**	**10**	**2,5**	**5,6**	**10**	**2,5**	**5,6**	**10**	**2,5**	**5,6**	**10**
4	–	–	–	–	–	–	–	–	–	–	–	–
10	564	–	–	–	–	–	169	542	–	–	–	–
16	146	454	–	1 120	–	–	56	143	309	–	–	–
25	52	132	283	211	913	–	22	51	98	940	–	–
50	12	28	52	37	96	211	5	12	22	190	460	940
100	3	7	12	9	20	37	1	3	5	45	100	190
* Austenitic non magnetic.												

Extract from IEC 62305-3

A cross-section of 50 mm² is required for direct lightning conductors in IEC 62305-3.

However tests made on various materials (such as ferrous steel and stainless steel) and presented in [*90*: *DE95016094[1].pdf*] reveal that the melted areas in both cases are not so different (at a continuing current of 800 A, the molten spot size is 143 mm² for stainless steel and 134 mm² for ferrous steel).

The following table from IEC 62305-1 and CIGRE gives the parameters related to direct lightning currents. The charge is typically ranging from 1.1 C to 150 C for single impulse and from 1.3 C to 350 C for a complete flash. It is more than enough to generate a hole on a 10 mm steel sheet.

Parameter	Fixed values for LPL I	Values			Type of stroke	Line in Figure A.5
		95 %	50 %	5 %		
I (kA)		4(98 %)	20(80 %)	90	*First negative short	1A+1B
	50	4,9	11,8	28,6	*Subsequent negative short	2
	200	4,6	35	250	First positive short (single)	3
Q_{flash} (C)		1,3	7,5	40	Negative flash	4
	300	20	80	350	Positive flash	5
Q_{short} (C)		1,1	4,5	20	First negative short	6
		0,22	0,95	4	Subsequent negative short	7
	100	2	16	150	First positive short (single)	8
W/R (kJ/Ω)		6	55	550	First negative short	9
		0,55	6	52	Subsequent negative short	10
	10 000	25	650	15 000	First positive short	11
di/dt_{max} (kA/μs)		9,1	24,3	65	*First negative short	12
		9,9	39,9	161,5	*Subsequent negative short	13
	20	0,2	2,4	32	First positive short	14
$di/dt_{30/90\ \%}$ (kA/μs)	200	4,1	20,1	98,5	*Subsequent negative short	15
Q_{long} (C)	200				Long	
t_{long} (s)	0,5				Long	
Front duration (μs)		1,8	5,5	18	First negative short	
		0,22	1,1	4,5	Subsequent negative short	
		3,5	22	200	First positive short (single)	
Stroke duration (μs)		30	75	200	First negative short	
		6,5	32	140	Subsequent negative short	
		25	230	2 000	First positive short (single)	
Time interval (ms)		7	33	150	Multiple negative strokes	
Total flash duration (ms)		0,15	13	1 100	Negative flash (all)	
		31	180	900	Negative flash (without single)	
		14	85	500	Positive flash	
NOTE The values of *I* = 4 kA and *I* = 20 kA correspond to a probability of 98 % and 80 %, respectively.						

Extract from IEC 62305-1

It appears that an arc generated by a direct or partial lightning current may well damage the CSST at the arc root.

Regarding possible surges generated inside the house, in the CSST circuit, we have to rely on [*111*: *Lightning overvoltages in wires within the buildings.pdf*]. Calculation of induced surges on 10-m and 20-m long wires in the case of a direct lightning on the structure shows a range from a dozen to a hundred volts or even to some kV, depending on the type of circuits. This may cause sparking over between the CSST and the metallic grounded parts or even between the electrical circuits and the CSST.

The IEC 62305-2 standard considers that dangerous lightning surges able to create a fire may be caused by lightning strikes up to 250 m from the structure perimeter.

For induced surges on external circuits, the same standard gives the following tables (slightly amended to make reading easier without knowing the complete standard).

	Aerial	Buried
A_l (direct strike on service)	(L_c) 6 H_c	(L_c) $\sqrt{\rho}$
A_i (induced surge on service)	1 000 L_c	25 $L_c\sqrt{\rho}$

Extract from IEC 62305-2

In our case (buried) the damaging surges are dependent on the length of the cable (Lc) as well as on the soil resistivity. It should be noticed that this standard is not related to risk of fire due to the induced surges, but rather to damages to electronic systems. In short, according to the IEC 62305 standard, the only way for a dangerous event to occur (such as fire or explosion) is either by a near strike generating high voltages in the structure circuits or by an indirect strike (strike to an underground service allowing the high partial lightning currents to penetrate the structure).

Considering the possible solutions (see IEC 62305-4) to mitigate the surges coming from the outdoor services, the first solution is the surge protective device for power/data line and the grounding of metal pipes (either direct or via a spark gap, as is often the case for cathodic protection reasons). For induced surges, the same standard indicates that equipotential bonding and proper cable routing are also key factors to reduce surges. In [*2*: *00736210.pdf*], the author presents the advantages and disadvantages of equipotentialization.

"Whenever possible, a single entry point should be used for all incoming services in order to avoid that part of the lightning current flows through the building.
Should this not be possible due, for example, to already existing and unchangeable separate entry points, large loops should be avoided by suitable cable routing inside the building. This is more effective (and, in most cases, cheaper) than a reduction of the impedance of the equipotentialization network.
Do not establish equipotentialization by multiple bonding of sensitive power or data cables to different potential reference points within a structure. An undefined current may flow in that case through such a link. That link may not be designed to withstand high alien currents.
Follow within the building a bonding and routing concept to interconnect different equipment."

This clearly states that, in a building where many services enter (such as gas, power line, and the like), bonding at the entrance may not be sufficient to avoid dangerous sparks inside the structure between these services, since they may not be bonded to the same ground or be at the same potential due to internal loops.

The effect of grounding is also discussed in [*148*: *wFoster-Miller report.pdf*]

"The grounding system must address low earth impedance as well as low resistance. A spectral study of lightning's typical impulse reveals both a high and low frequency content. The high frequency is associated with an extremely fast rising "front" on the order of 10 microseconds to peak current. The lower frequency component resides in the long, high energy "tail" or follow-on current in the impulse. The grounding system appears to the lightning impulse as a transmission line where wave propagation theory applies. A single point grounding system is achieved when all equipment within the structure(s) are connected to a master bus bar which in turn is bonded to the external grounding system at one point only. Earth loops and differential rise times must be avoided. The grounding system should be designed to reduce ac impedance and dc resistance. The shape and dimension of the earth termination system is more important a specific value of the earth electrode. The use of counterpoise or "crow's foot" radial techniques can lower impedance as they allow lightning energy to diverge as each buried conductor shares voltage gradients. Ground rings around structures are useful. They should be connected to the facility ground. Exothermic (welded) connectors are recommended in all circumstances."

This clearly states that a common grounding point is needed and that this grounding should be of low of impedance and of low resistance. One of the contacted experts informed us of the high frequency measurements he has carried out on various grounding elements of structures damaged by lightning where CSST may have been involved. His written report was not available at the time of this report.

5. GAP ANALYSIS

5.1. Summary of the literature review and of the consultation with experts – preliminary conclusions

After inspecting pictures of damages that we provided, the international lightning experts—who were not involved in the CSST case studies—believe that the observed holes may not be caused by induced surges but by direct lightning currents or by partial lightning currents. Power fault current is also considered as a possible cause for such holes. Some experts directly involved in the CSST case studies even considered power fault current to be the main cause of damages. However, at least a few examples have been provided where it can be shown that electrical lines were not involved.

Induced lightning is represented by a weaker impulse (8/20 µs wave) compared to direct lightning (10/350 µs). The duration of induced lightning is short in comparison to the duration of direct lightning strike. A partial direct lightning has the same duration but a smaller magnitude compared to a direct strike.

Induced lightning can create damaging surges (even if 8/20 waves) in some cases. These surges are created by a source (a lightning current creating a magnetic field, stronger if nearer) and a receptor (the loop between a long overhead power line and the earth, for example). Induced surges are also created on underground lines, but they are weaker and mainly dependent on the soil resistivity.
In the US, gas is supplied to a facility by tanks adjacent to the facility, by buried or aboveground tanks, remote to the facility, connected by buried metallic piping and by buried municipal service using either metallic or plastic (Polyethylene) piping to the service entry. In all these circumstances, the induced surges are probably weak. The

induced surges may create a sparkover between CSST exposed to an induced voltage and another metallic grounded part (especially when the supply is made of copper or black pipe with no bonding at the service entrance of the installation).

However, based on some CSST cases studied, holes do not always occur where the distance between the CSST and a metallic part is the smallest.

Holes also occur when the supply pipe is short (such as when the tank is in the vicinity of the house). It seems that the voltage is then directly induced onto the runs of CSST and not propagating from the gas supply. In that case, is the loop long enough to allow the creation of damaging voltages?

Further studies (simulations) and tests will help understanding the magnitude of such surges and whether they could be damaging. The loop may be between the power line and the CSST for example, but is it really possible to create a high voltage over a run of a few meters of CSST? The loops could be made from the internal CSST routing with terminations at electrical service grounds. In some cases, these could be very large loops.

Experts involved in CSST case studies primarily consider damages resulting from direct lightning strikes to the structure, induced lightning, or power fault currents. If the surges are coming from the power network, it may be easier to explain the damages, as the surges are probably stronger (because of bigger loops), but a few cases of damages occurred far away from the power conductors or when power had been previously lost to the structure.

It is then likely that there is not a single mode of damage. Damages may be created by a direct strike to the structure, induced surges to incoming power lines, or partial direct lightning current from a nearby strike.

In the case of direct strike to the structure, the presence of a lightning protection system per NFPA 780 needs to be considered. In fact, if protection against direct lightning is not considered for a specific building, we cannot expect CSST to survive through such an event.

For induced surges, the energy may be induced on the power circuit or on the CSST circuit itself. Solutions may be different for these two cases. Appropriate bonding of the CSST may be a solution, but a separation distance between CSST and other metallic circuits (such as chimneys or power lines) may be an alternative solution or even a combined solution. Such requirements appear in the latest installation rules for some manufacturers.

One of the involved experts has discussed the efficiency of the bonding in terms of high frequency. Lightning is a high frequency event and it is known that at 1 MHz for direct strikes 1 m of copper link may lead to a voltage drop of 1 kV or more. Not only does the ground to which the CSST is bonded need to be of low impedance (and probably lower than the other circuits, including the gas tank itself), but also the length of the bond needs to be short. In some of the cases we have studied, the only bonding was in the attic at the manifold (which means that the bond was probably quite long) with bends at angles of less than 90 degrees, which is probably not sufficient to be efficient at high frequencies.

It is interesting to note that CSST damages due to lightning is most prevalent in the USA. Many countries have no feedback but they are using either short length of CSST (UK) or their use of CSST is quite recent (France). In some cases, CSST is used in only one application (South Korea). It is interesting to note that Japan, which is apparently the prime developer of CSST, is also recording a few damages, and some warnings appear in installation documents regarding bonding and proximity to metallic parts. However, the only country for which list of damages can be easily found on the Web or in magazines is the USA. This may be due to a larger use of CSST or, as explained by one of the manufacturers, less stringent rules for equipotential bonding in the US as well as more use of non-metallic conductors in houses (plastic pipe instead of metal pipes, wifi instead of cables, and so on); in these cases, CSST remains one of the few metallic skeletons of a house and is therefore more stressed than it was in the past.

The data provided were either specific but too limited in quantity or too broad in scope to be adequate to develop a complete risk context for CSST damage. In addition, the amount of relevant data obtained came from a limited number of sources in spite of a large list of contacts (see Annex 1). This has an impact on the credibility of any conclusions and gap analysis that could be drawn from the data.

5.2. Preliminary answers to the questions raised at the origin of the study

We need to try to answer the questions raised by the CSST Task Group based on the analysis done as a first attempt to fill the gap.

- Validate **whether or not bonding** of CSST is an adequate solution to lightning exposure problem.
    - It is probably not the only solution in the case of direct lightning strikes. Future studies and testing are needed to check what to do when a lightning protection system is implemented on a house according to NFPA 780. When there is no lightning protection system, bonding alone cannot solve the problem, especially with a #6 AWG bonding conductor. Lightning protection in IEC 62305 requires 0 AWG for the direct lightning path. This is not a good comparison without additional explanation. The intent of the 6 AWG is not to serve as a primary current conductor but instead to simply handle enough current to provide potential equalization. However, in some cases the CSST bonding is the single or main path to

the earth and # 6 AWG may not survive such a stress.

  - For induced and indirect lightning, bonding at the entrance of the installation will help reduce the stress but, as stated by many experts, a global equipotential solution is required to achieve a complete solution, especially when the lightning threat does not come from the gas supply network. Experience with problems occurring in spite of bonding is quite small. However, one expert data set showed that about twice as many incidents with damage had bonding at the time as did not.

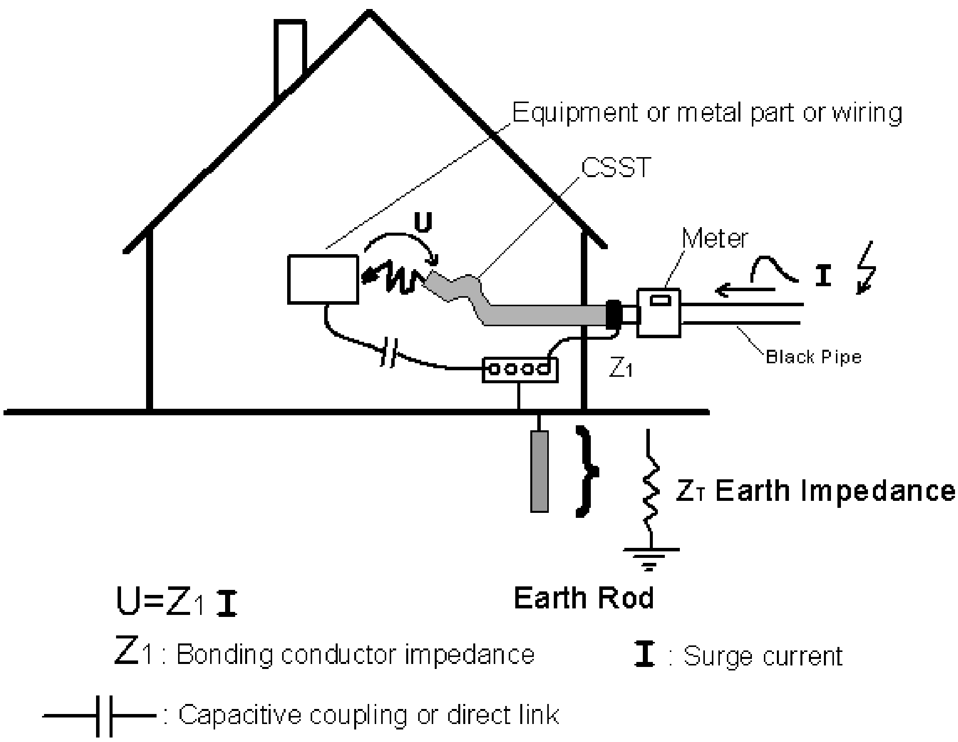
- If bonding is the solution, validate **how bonding should be done**.
  - Bonding should be done with short length conductors, whatever is the source of lightning threat. Additional measures need to be defined when short length conductors are not achievable. Test and/or simulations are needed to fix limits.
- If bonding is the solution, validate **the size of the bonding jumpers**.
  - The bonding with#6 AWG needs to be validated by more tests, as the tests performed do not cover the complete picture.
  - A specific study should define the size of the bonding conductors and the acceptable length and location of these conductors (this size may be bigger than indicated above in the case of direct lightning threat).
- Determine **if bonding should be done at a location or locations other than where the gas pipe enters the building**.
  - This answer is covered by the previous points. A specific study should define the size of bonding conductors and the acceptable length and the location of these conductors.
- Determine if alternate methods can be used for safe installation (such as **separation from other equipment)**.
  - It may be necessary to define separation distances instead of or in addition to the bonding at the entrance point. Simulations and tests should demonstrate the need. Alternatively, CSST specifically designed to have an enhanced lightning surge withstand may be used.

Note: *Adequate* needs to be defined in terms of percentage of efficiency. IEC 62305 defines, for example, 4 levels of efficiency for lightning protection systems (98%, 95%; 90% and 80%). According to this definition, 100% efficiency cannot be obtained even with lightning protection measures.

5.3. Possible scenarios

To determine if the bonding solution as defined in NFPA 54 is adequate, possible threat scenarios should be defined. Normally, field experience should validate these scenarios and their associated probabilities, but field experience is so limited that many scenarios will remain hypothetical. However, determining these scenarios is a necessary step to filling the gap.

Scenario a)



Scenario a)

This is the typical arrangement covered by NFPA 54. A metallic pipe supplies gas to the house. The CCST installation starts at the entrance point. Bonding to the electrical supply ground is achieved by a link of impedance Z1 (lightning is both high frequency—up to 1 MHz—and low frequency; high frequency creates the sparkovers and overvoltages, while low frequency is related to energy. Thus any component should be characterized by impedance and not only resistance). The earth rod has an earth impedance. Many metal parts and conductors are connected to the grounding electrode, but some of them are only related to this grounding electrode by capacitive coupling. In any case, they have a voltage determined by the grounding electrode one way or another. Bonding the CSST helps to decrease the stress and its efficiency is related to its capacity to conduct the lightning current I, as well as maintain CCST voltage near the ground rod voltage. A bonding conductor of 6 AWG is what is required by IEC 62305 for equipotential bonding, and is therefore adequate to handle the lightning energy. If the bonding conductor is too long, CCST will then be at a high voltage $U = Z_1 I$ and can sparkover to a grounded metal part in the vicinity. Acceptable separation distance depends on voltage U and thus on current I and impedance Z_1. If the length of the bonding conductor increases, the separation distance must increase accordingly. Multiple bonding will help reduce the stress very efficiently. If we assume that the bonding conductor is mainly an inductance (typical value of 1µH/m) and that the front of the current impulse waveform is 20 kA/µs (see table copied from IEC 62305 already discussed), we get a voltage U = L di/dt, and for 1 m of bonding conductor this equals 20 kV. If the bonding conductor is long enough, this can lead to a sparkover between CCST and a metal element in the vicinity.

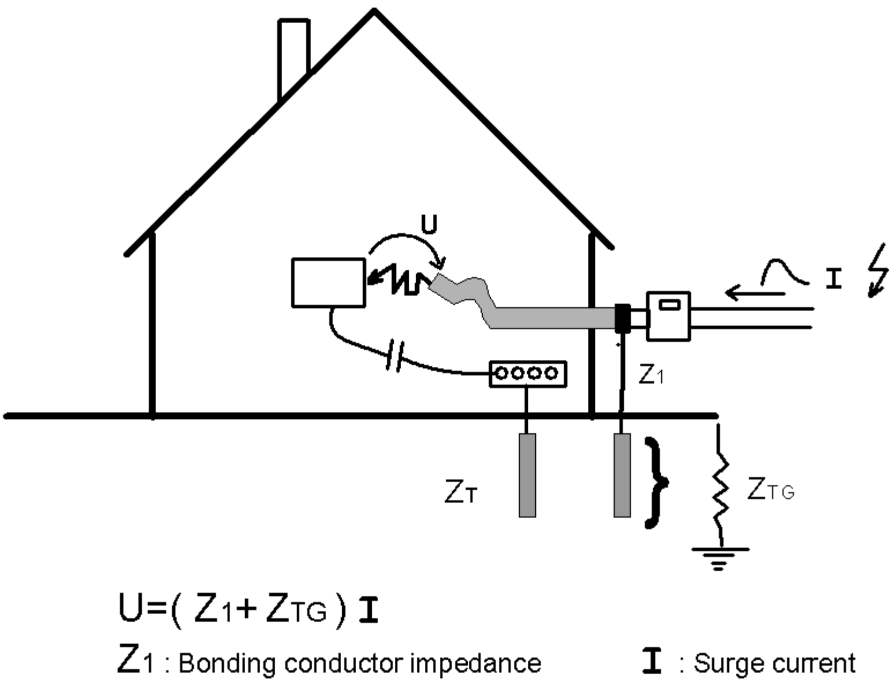
Simulations are needed to show if separation distance is needed based on bonding conductor length and possible lighting currents given from the standard database.

This scenario is typically what is covered by tests published so far.

A bonding conductor at the entrance may not be enough if the bonding conductor is too long. In that case, multiple bonding points or a separation distance would solve the problem.

An example of such a scenario can be found in case A3.27.

Scenario b)

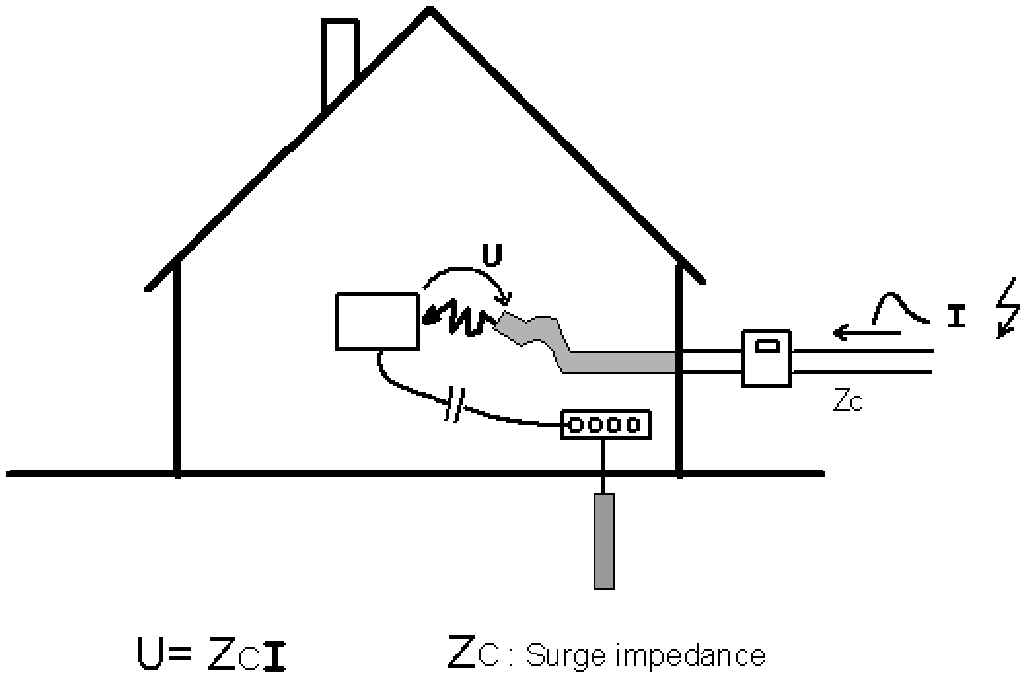


Scenario b)

Scenario b is similar to scenario a. The only difference is that bonding of CSST is made to a different ground rod than is grounding for the electrical supply. In such a case, the CSST voltage becomes U = (Z_1 + Z_{TG}) I where Z_{TG} is the CSST ground rod impedance. This voltage is greater than in case a), and this shows the benefit of equipotential bonding (all ground rods connected together). A typical value of Z_{TG} is 40 ohms, and we take the same voltage drop in the bonding conductor as in scenario a) plus a surge current value of 1 kA. The voltage becomes U = 20 kV + 40 kV = 60 kV for 1 m of bonding conductor.

An example of such a scenario can be found in case A3.11.

Scenario c)



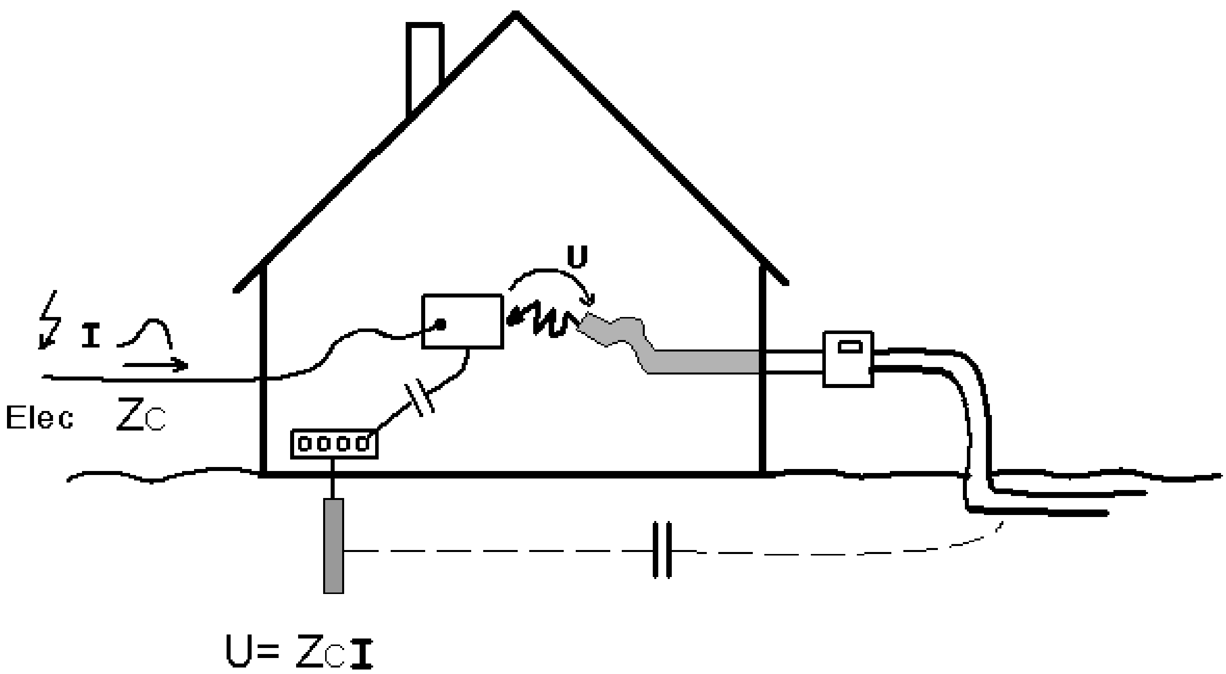
Scenario c)

Scenario c is similar to a) and b), but in this case there is no CSST bonding at all.

We don't know at this stage what the surge impedance Z_c of the CSST may be, but if we base our calculations on power lines, typical surge impedance is on the order of a few hundred ohms. For a surge current of 1 kA (bottom value for lightning current), the voltage $U = Z_c I$ would be above 100 kV, far greater than in the scenarios above. If the current becomes high enough, the voltage can lead to a sparkover between CSST and metal elements in the vicinity. This is obviously the worse case, and the bonding solution shows its benefit.

An example of such a scenario can be found in case A3.13.

Scenario d)



Scenario d)

In this scenario, the threat is coming from the electrical line. If we assume a 300 ohm surge impedance we get a voltage U = 300 kV for a 1 kA surge current. This can lead to a sparkover between the electrical conductors and the CSST. The arc created between the electrical conductor and CSST would then be energized by the power fault current finding its path back to ground through the coupling between CSST and ground.

In this scenario, the benefit of the bonding of CSST is given by the ability to create a larger fault current and thus a quicker response of electrical overcurrent protective means (such as fuses or circuit breakers). In fact, if the CSST is bonded to the electrical ground, the path for the fault current to return to ground is of smaller resistance (direct bonding in spite of de facto bonding of CSST). However, it is not clear if CSST can survive a large fault current even if for a short time.

When CSST is not properly bonded, the fault current is smaller but the overcurrent protective means takes longer to function (if at all). On the other hand, the bonding will allow the overcurrent protective means to work more quickly, but at the same time the damage can be greater due to the larger fault current.

Tests should be made to check the ability of CSST to withstand small fault current for a long time and higher fault current for a shorter time.

These tests will demonstrate if bonding at the entrance is sufficient, or if multiple bonding or even separation distance is needed.

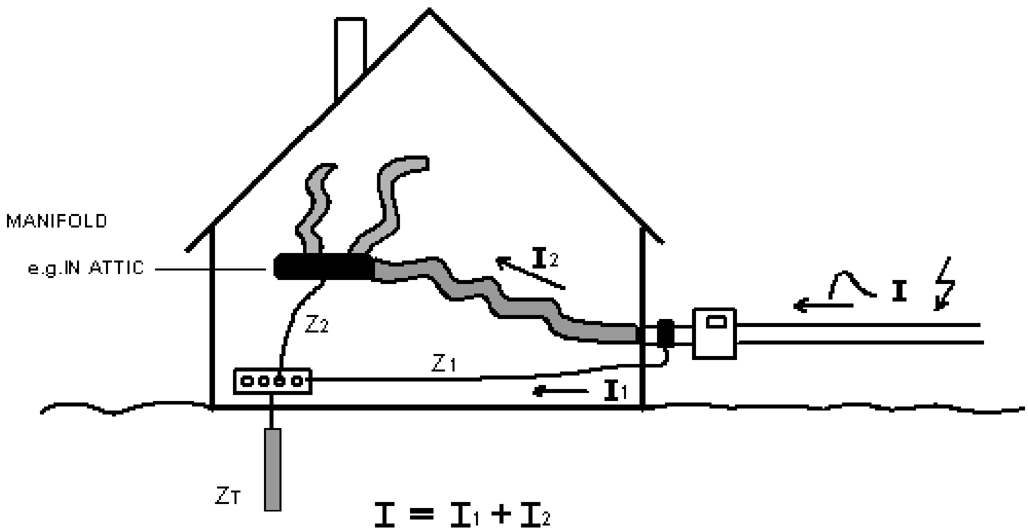
In that scenario, another solution is either a surge protective device (SPD) at electrical panel or an equipotential bonding SPD between the electrical line and CSST where the distance between CSST and electrical conductors is the smallest.

> Note: In the case of a fault on power line, there is not enough voltage to break the gap between CSST and the electrical conductors. Voltage high enough to break that gap (creating a sparkover) can only be obtained by lightning surges (direct, induced, or indirect) on power lines.

An example of such a scenario can possibly be found in case A3.17.

We can also imagine another scenario based on d) where a lightning surge damages equipment to which both CSST and electrical lines are connected. The lightning surge can create an arc both between electrical conductors and CSST and between CSST and a metal part. The fault current then flows along CSST to reach the metal part. The phenomenon remains the same.

Scenario e)



Scenario e)

Scenario e) is based on scenario a), but another bonding conductor exists elsewhere in the installation (in the above figure, the additional bonding is at the manifold; this has been seen in some real cases).

The surge current I shares between the two paths to ground, corresponding to the two bonding conductors. A partial surge current flows along CSST until it reaches the second bonding point. This shouldn't create any problem except if the surge current I_2

becomes too large for the cross-section area of CSST or if voltage drop along CSST becomes larger due to inductive effect. **Confirmation that scenario e) is unlikely to create a major problem can be derived from other tests that will be discussed later on where surge current flows along CSST**. However, steel is known to have a poor resistivity, and this scenario cannot be ruled out without any check. Tests performed so far for which results have been published do not cover this case because most of the surge current delivered by the generator returns back to the generator; and the part of the surge current flowing along CSST is limited to the part of current flowing through the arc.

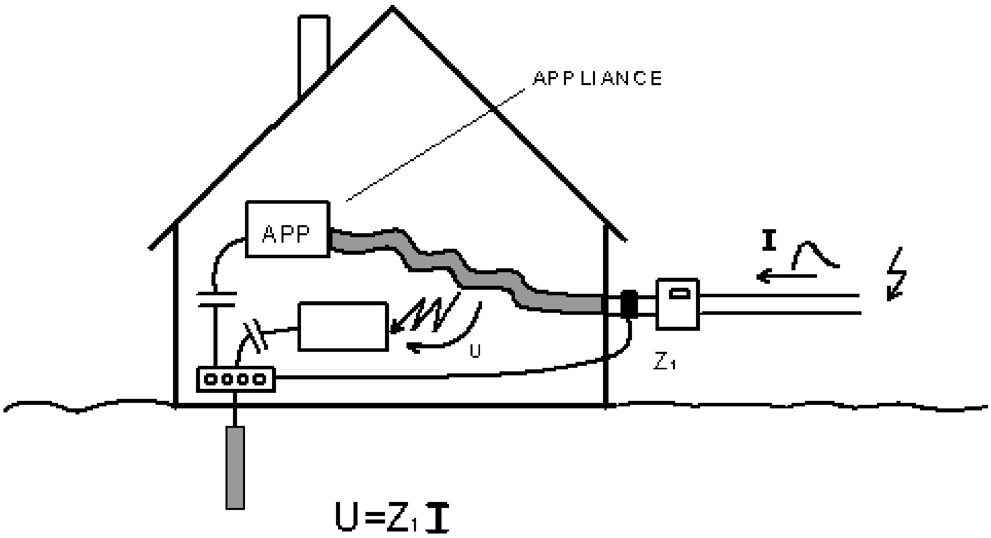
> Note: Tests performed so far are with generator electrodes too near each other to allow a large surge current to flow along CSST. The effect of partial surge current flowing along CSST is then not fully covered by tests published so far.

A second problem that can appear in that scenario comes from the impedance of the CSST (unknown so far). When current I_2 flows along CSST, it will create a voltage U = Z_{CCST} I_2, this voltage can be high enough to create a sparkover between CSST and a metal element in the vicinity.

It is necessary, then, to perform tests to know what the impedance (mainly inductance) of CSST is.

An example of such a scenario can possibly be found in case A3.26.

Scenario f)

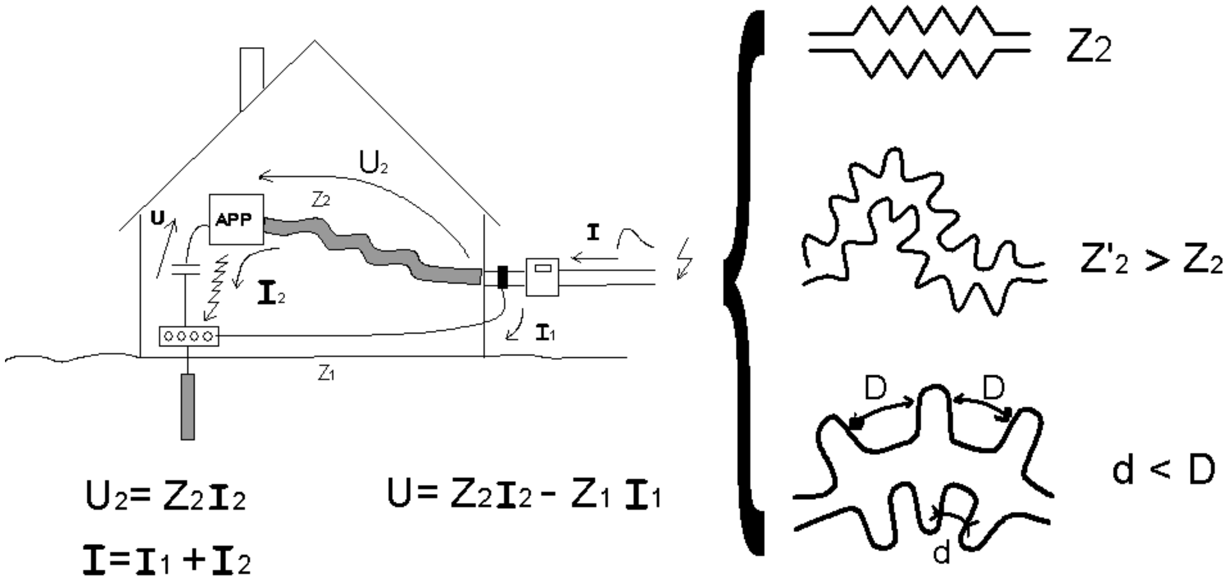


Scenario f)

Scenario f) is close to previous scenarios [especially a) and e)], but the CSST connection to an appliance is also involved. If this appliance is grounded, the scenario is equivalent to scenario e). If the appliance is grounded through a different circuit, the scenario is closer to scenario a).

Examples of such a scenario are covered by scenarios a) and e).

Scenario g)



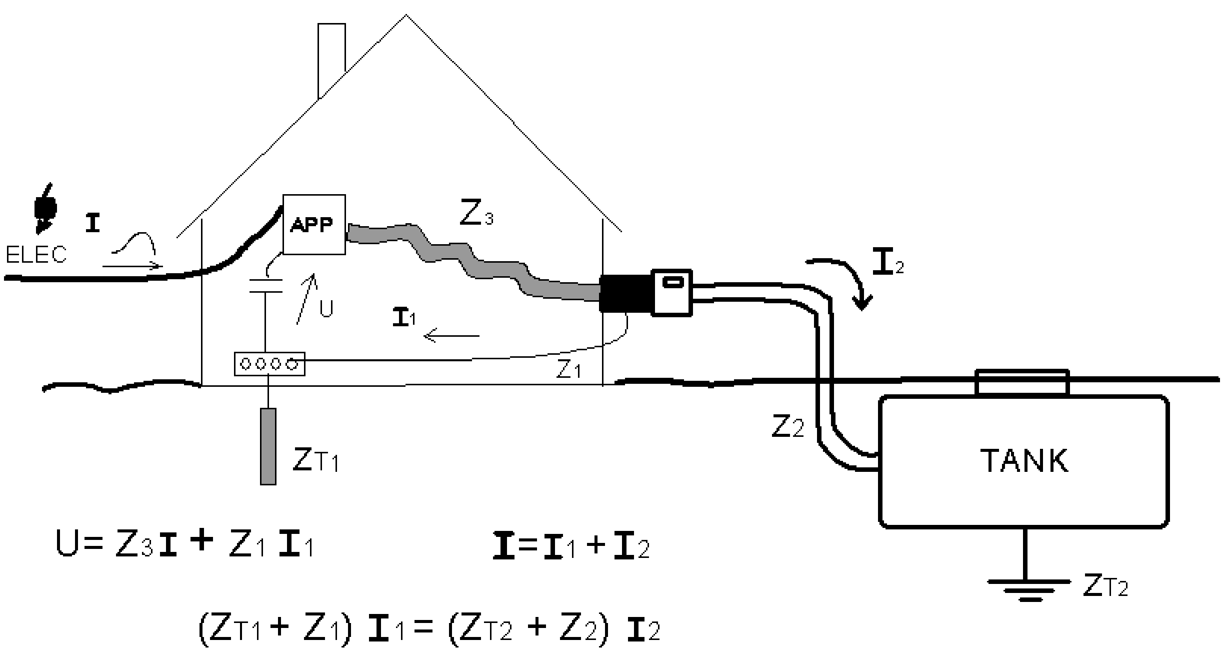
Scenario g)

This scenario emphasizes the effect of the CSST impedance. It is based on scenario e). Whatever the inductance Z_2 of CSST may be, it is clear that the impedance will be slightly more when a bend exists (Z'_2). **Tests to determine CSST impedance should incorporate maximum bending radii as given in technical brochures.**

The effect of bends should be investigated. There are cases where multiple holes have been found on CSST without clear explanation (when a sparkover exists somewhere, this normally drops the voltage and reduces the probability another sparkover will occur, especially in close vicinity). The bending effect—where some ridges of the CSST (inside the bend) are nearer than other parts (outside the bend) — could be an explanation that needs to be investigated. Apparently, around 50% of the cases where this occurred were related to direct lightning strikes and we have already said that direct lightning withstand can probably be disregarded (this should be within the scope of NFPA 780). Cases were reported where adjacent holes occurred without a direct strike to the house, and cases were reported where a hole was found far from any metal part.

An example of multiple holes can be found in case A3.1.
An example of holes with no metal part in the vicinity can be found in case A3.14.

Scenario h)

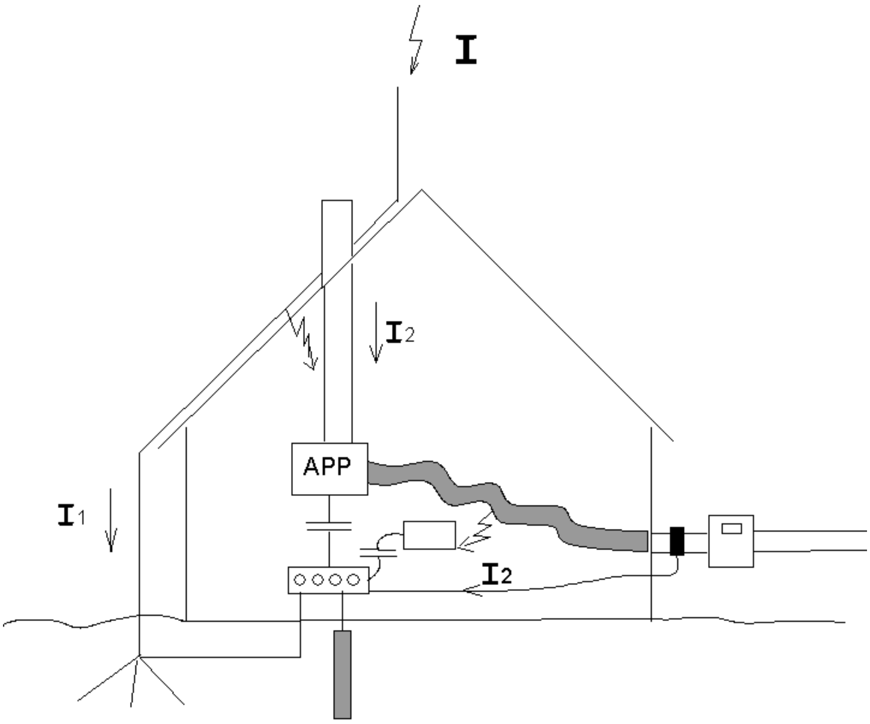


Scenario h)

In this scenario, the surge current comes from the power supply. The gas supply is an underground tank as observed in a few cases described to us. This gas tank has a natural earth impedance Z_{T2} . Flashover may occur inside the powered appliance and the surge current then flows to both groundings (power supply rod and gas tank). The phenomenon involved is similar for black pipe and CSST as it is for appliance damage. The solution in that case is probably an SPD on the power line.

An example of such a scenario can possibly be found in case A3.7.

Scenario i)

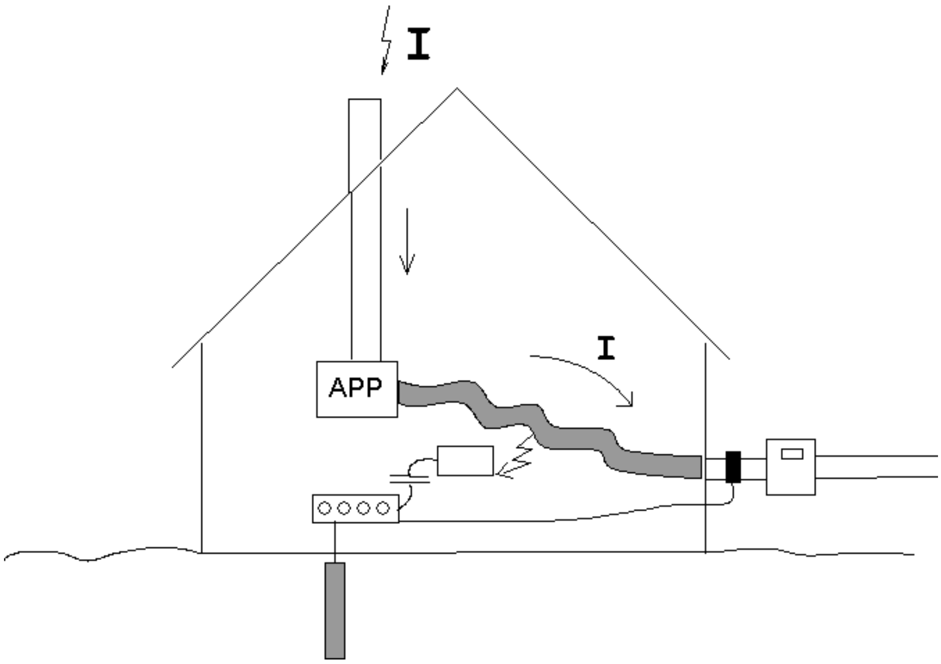


Scenario i)

Scenario i) considers a house equipped with a lightning protection system (LPS). In case of lightning strike on the LPS, the current I flowing along the down-conductor creates a high voltage at the house top that may lead to a sparkover at roof level, to a metal chimney for example. A part of the surge current I will then flow along the metal chimney, then inside the appliance, leading to a partial current flowing along CSST. Once again in that scenario, the damage is likely to occur inside the appliance. The current flowing along CSST can also create a sparkover somewhere where distance between CSST and a grounded metal part is smallest. The solution in this case is global equipotential bonding, but this should fall under the rules of NFPA 780. This is basically a matter to be resolved by mutual information sharing between the CSST and LPS contractors to ensure that this additional stress on CSST installation remains under control.

The flow of partial lightning current along CSST is not completely covered by tests published so far.

Scenario j)

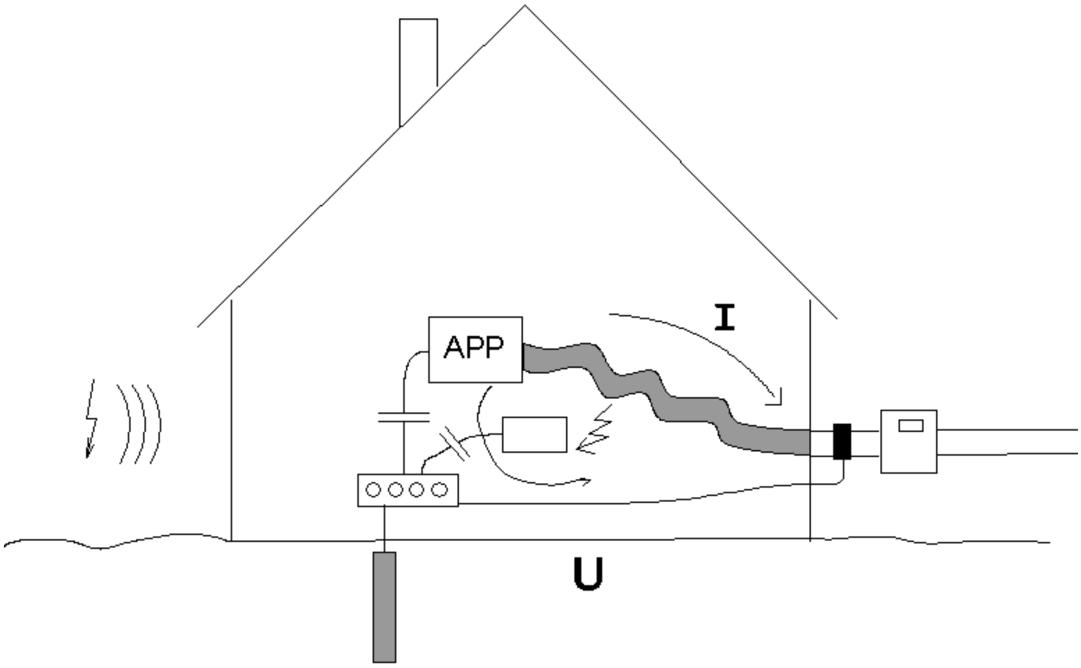


Scenario j)

In this scenario, there is also a direct strike to the building, but no LPS is present. The chimney on the roof is struck by lightning, and current flows through an appliance and then through CSST. It is likely that this will create damage at the appliance, but a sparkover can occur between CSST and a metal part in the vicinity. However, why CSST should withstand this stress when the complete house is in danger due to the direct lightning hit itself is in question. To be sure that CSST can withstand such a stress, an LPS is needed on the house, or at least rules for equipotential bonding given in NFPA 780 should be applied to CSST whether an LPS is present or not.
We do not suggest performing tests to cover such a scenario.

An example of such a scenario can be found in case A3.4.

Scenario k)



Scenario k)

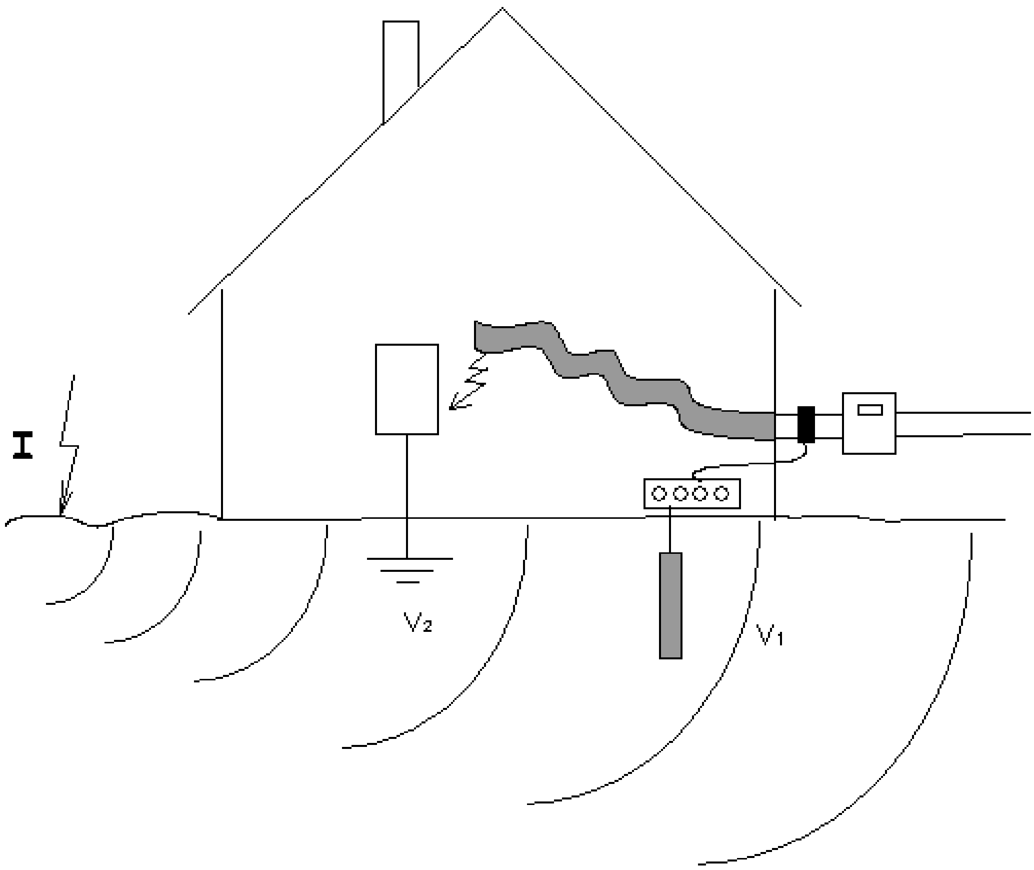
Scenario k) covers the case of a lightning strike in the vicinity of the house, close enough to create a high voltage on the CSST installation (which is a loop). When the voltage is high enough, a sparkover will occur somewhere and an induced current will flow in the CSST circuit. According to IEC 62305-2, a dangerous spark can only occur when the lightning strike is less than 250 m from the house. In such a case, the best way to protect CSST is to create bonding on the CSST to decrease the size of the loop. Bonding at CSST, at manifold, and if possible at appliances would be a good solution, since it would reduce the size of the loop. One expert declared that the non-systematic equipotential bonding approach was the cause of the problem. Scenario k) supports his position. **Tests should however be performed with 8/20 impulses** (representing induced surges) to determine whether these impulses can damage CSST if multiple bonding is not provided.

Based on tests results, it will be possible to determine if multiple bonding is necessary of not.

Note: according to tests published, 8/20 wave has also been used but:

- the test layout used for these tests is probably not covering all cases
- it has been mentioned in published tests reports that 10/300 was preferred and only 10/300 results have been reported

Scenario l)



Scenario l)

Scenario l) represents the case of a direct strike to the ground or a grounded structure (such as a tree or a pole) in the vicinity of the house. The lightning current creates equipotential spheres in the soil, which leads to different soil voltages at different locations (this helps explain the well known step voltage problem leading to many cows' deaths when lightning occurs). If metal parts of the house (for example columns, steel beam, or concrete walls) are in contact with the soil, we will experience a voltage V2 that may be different from the voltage at the gas installation (or electrical ground rod). This voltage can be high enough to create a sparkover between this metal part and the CSST. A partial lightning current is then flowing through the arc and the CSST.

This scenario is not fully covered by tests published so far. **Additional tests are needed. Separation distance and multiple bonding are possible solutions to the problem.**

An example of such a scenario can possibly be found in case A3.9.

If we consider purely CSST (and thus neglect the effect of electrical wiring for example) the most important scenarios are a), f), k), and l).

When direct lightning is concerned, scenario g) may also be important. Scenario g) may also be important for indirect lightning current, as this scenario seems to be the only candidate to explain some of the observed failures.

Scenario b) considers bonding to different grounding. This should be avoided in new installations, in order to comply with international equipotential bonding rules.

Scenario c) has no bonding at all; this should also be avoided.

Scenario d) and h) cover a threat coming from power lines.

Scenario e) is similar to scenario f) and covers the case of multiple bonding of CSST (in some case due to appliance bonding) where partial lightning current may flow along a certain length of CSST.

Scenario i) covers the case of a structure protected by a lightning protection system, while scenario j) covers the case of direct lightning on an unprotected structure.

5.4. Conclusions

It would have been nice to have enough field experience to determine if all the scenarios described above really need to be considered. Since we do not have this experience, we have to consider the scenarios that have not been disregarded in our analysis as valid. Most of them have been validated by at least one documented case.
It should be noted that the number of documented incidents for which we have detailed data is far too small to derive any pertinent statistics or even trends.

Based on the limited number of incidents reported to us (around 140), the number of incidents of lightning induced damages to CSST may seem to be no greater than lightning damages to the electric distribution systems within residential buildings. However, the purpose of this study is to concentrate on CSST incidents only.
The scenario analysis, when compared to tests published so far (or simulations, should it be difficult to carry out some tests due to laboratory limitations when long lengths of CSST are required) have shown that some tests are missing.

For the sake of clarity, we repeat below the main statements given in the scenario clause:

- Simulations are needed to show if separation distance is needed based on bonding conductor length and possible lightning currents given from the standard database. Bonding conductors located at the entrance may not be enough if the bonding conductors are too long. In that case, multiple bonding or separation distance may solve the problem (please note that a few cases have shown that incidents occurred in spite of apparent sufficient separation distance).

- Tests should be made to check the ability of CSST to withstand small fault current for a long time, as well as higher fault current for a shorter time.
- It should be confirmed that multiple bonding is unlikely to create a major problem when surge current is flowing along CSST.
- Tests should be performed to identify the impedance (mainly inductance) of CSST per unit measure.
- Tests to determine CSST impedance should incorporate the maximum bending radius as given in technical brochures. The effect of bends should be investigated.
- Tests should be performed with 8/20 impulses (representing induced surges) to see if this can damage CSST if multiple bonding is not provided.
- Based on tests results, it will be possible to determine if multiple bonding is necessary of not.

The needed tests and simulations are described below. With four types of test, all scenarios can be covered. Testing means are not described in detail when they use generic generators and configurations typical for lightning tests. In that case, only the type of generator is given (i.e. 10/350 or 8/20). Please note that tests need to be performed with current generators and not combination wave generators. For each of the proposed tests, the purpose of the test is described. For tests that are not typical tests to the lightning protection industry (such as the third proposed test), a test layout is also described.

It is likely that tests need to be performed on many CSST brands, especially if the installation requirements differ from one manufacturer to another. Specific products designed to enhance their surge withstand capability should also be tested this way.

First, a test is needed with a lightning current generator injecting a 10/350 surge current in a given length of CSST. The magnitude of current should be based on lightning standards such as IEC 62305. The length of CSST should first be tested straight, and then a similar sample tested with the maximum bending radius allowed by the manufacturer.

Purposes:

- check temperature rise (possible heating in CSST due to lightning current flow)
- determine maximum withstand current
- observe possible mechanical damage or local effect of the corrugated surface
- use these test data to suggest new requirements in NFPA 780 and possibly NFPA 54 for a common bonding approach
- determine the possible behavior of CSST when a direct strike occurs on a structure not protected by a LPS
- try to explain the observed holes in CSST
- confirm that 6 AWG is the right size conductor to protect against partial direct lightning, or indicate if the size should be increased

This test covers scenarios e), f), i), j), l) and possibly g).

Second, another test is needed with a steeper front surge current (1 µs rise time, for example) injected onto a significant length of CSST. As in the first test, the CSST samples should be first configured straight, then with the maximum bending radius allowed by the manufacturer.

Purposes:

- determine the high frequency behavior of CSST
- try to explain the observed holes
- allow a computer simulation to be made to determine the rules for multiple bonding or separation distance. For example, if the length of bonding conductor

is greater than xx feet, then another bonding means is necessary or a yy inches (or feet) separation distance is needed.

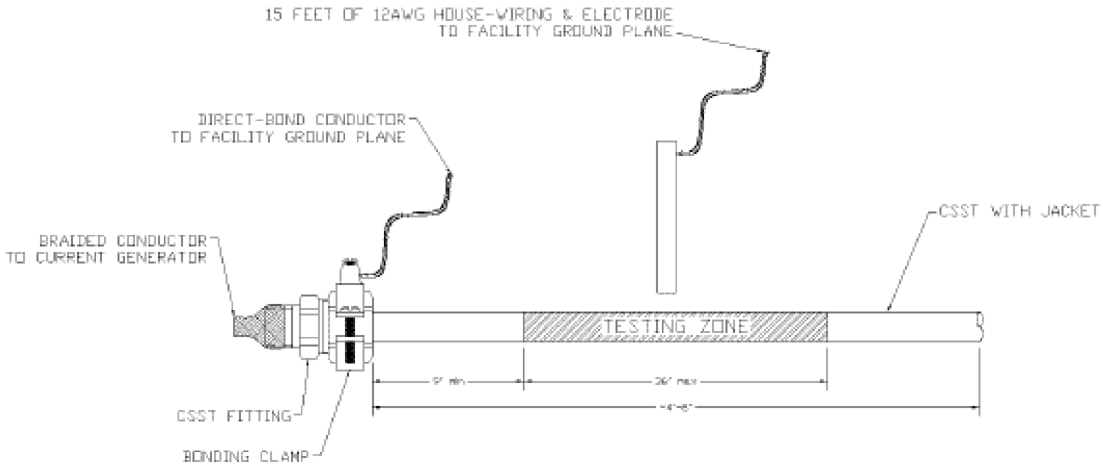
Note: CSST inductance can also be measured with other testing means.

This test covers scenarios g) and k).

Third, a test with the layout described below is suggested. We suggest the use of a 10/350 current generator (direct strike), a 8/20 current generator (induced strike), and a test generator capable of generating steeper front of wave (typical of the second impulse in a multiple impulse lighting strike. This might be a challenge since the length of CSST and of the 6 AWG bonding conductor will probably have a major influence on the generator output. It could be met by using computer simulations combined with laboratory tests. Computer simulations should define the worst case, and the testing generator should be adjusted to reproduce the effect of this worse case). The possibility of creating the arc by a fuse link instead of a gap between CSST and an electrode should be investigated; the result will be less dependent on bonding conductor length and could probably decrease number of tests to be performed (there is available published literature covering such test procedures).

Purposes:

- demonstrate the influence of the CSST impedance against all types of lightning stresses
- confirm that 6 AWG is the right size to protect against indirect and induced lightning
- check the effect of the arc on CSST depending on current, waveshape, CSST length, and bonding conductor length
- determine maximum values for bonding conductor length without additional bonding or separation distance, based on tests (and, if needed, tests combined with simulations)
- check that for induced lightning the risk of damage to CSST is minimum



Test Layout Scheme

This test covers scenarios a), e), f) and l).

Fourth, a test should be performed which injects power fault current in CSST at a supposed arc location. Values for time and current should be based on protection rules existing in power installations.

Purposes:

- check the ability of CSST to withstand small power fault current for a long time
- check ability of CSST to withstand higher power fault current for a shorter time
- indicate if bonding is creating more drawbacks than it is providing advantages, in the case of an arc to CSST coming from the power line
- if drawbacks occur, this will help determine the separation distance needed between power conductors and CSST

  Note: in this case the proper protection needed may be a surge protective device on the power line.

This test covers scenarios d) and h)

Tests are summarized in the following table.

Test No.	Description of test	How to apply the test	Main knowledge gained from the test	Scenario no. covered by the test°
1	Direct lightning surge current test	Directly on CSST length either straight or bended	• check temperature rise • determine maximum withstand current • observe possible mechanical damage or effect of corrugated surface • determine the possible behavior of CSST when direct strike occurs on a structure not protected by a LPS	e), f), i), j), l), Possibly g)
2	Steep front surge current test	Directly on CSST length either straight or with bends	• determine the high frequency behavior of CSST • allow computer simulation to be made to determine the rules for multiple bonding or separation distance	g), k)

Test No.	Description of test	How to apply the test	Main knowledge gained from the test	Scenario no. covered by the test°
3	Main test	On complete configuration with bonding conductor and arc	• demonstrate the influence of the CSST impedance for all types of lightning stresses • confirm that 6 AWG is the right size for indirect and induced lightning check the effect of the arc on CSST depending on current, waveshape, CSST length, and bonding conductor length • determine maximum values for bonding conductor length without additional bonding or separation distance, based on tests combined with simulations if needed	a), e), f), l)

Test No.	Description of test	How to apply the test	Main knowledge gained from the test	Scenario no. covered by the test°
4	Power fault current test	Inject a power fault current to CSST	• check ability of CSST to withstand small power fault current for a long time and higher power fault current for a shorter time	d),h)

Proposed Tests Summary

Recommendations: To cover the full picture, the 4 tests described above need to be performed. However, this may lead to long and costly tests.

We suggest the minimum test program, depending on what is supposed to be covered:

If direct lightning threat to the structure is disregarded, the first test may be skipped.

The second test then needs to be performed to obtain data on the behavior of CSST and allow future simulations to be done. These simulations will allow us to determine the bonding conductor admissible length, the rules to follow when multiple bonding is needed, and the acceptable separation distance needed.

The third test is the most important and needs to be performed.

If the threat coming from power lines and power fault current is disregarded, the fourth and last test may be skipped.

Before concluding, it should also be noted that a lightning protection system (LPS) is essential for protection against direct strikes. Without the LPS, no amount of bonding is sufficient and no metallic system within the house is safe from some level of damage from lightning. For bonding to be effective, a “global equipotential solution” is required.

We are now in a better position to answer to questions raised at the beginning of the study:

- Validate **whether or not** bonding of CSST is an adequate solution to lightning exposure problem.
    - CSST is probably not the only solution in the case of direct lightning strikes, but protection should be provided in that case based on NFPA 780.
    - For induced and indirect lightning, bonding at the entrance of the installation will help reduce the stress but, as stated by many experts, a global equipotential solution is necessary to achieve a complete solution. Separation distance is another way to solve the problem, but this could be difficult to implement in real applications. Alternatively, CSST specifically designed to have an enhanced lightning surge withstand may be considered, provided their behavior is supported by tests.

      It is noted that in some cases bonding is not at the entrance but further along the installation (for example at manifold in the attic) and this is probably less effective because the long bonding conductors provide less protection.
- If bonding is the solution, validate **how bonding should be done**.
    - Bonding should be done with a short length of conductor with minimum bends, regardless of the source of lightning threat. Acceptable bonding length can be determined through tests supplemented with computer simulations.
- If bonding is the solution, validate **the size of the bonding jumpers**.
    - Bonding with 6 AWG needs to be validated by more tests; the tests published so far do not cover the complete picture, even though 6 AWG is the normal size for equipotential bonding conductors and this size should be adequate.

- Determine **if bonding should be done at a location or locations other than where the gas pipe enters the building**.
    - Multiple bonding would help to avoid stress coming from induced surges. It can also help in other cases, such as when the bonding conductor is too long.
- Determine if alternate methods can be used for safe installation, such as "**separation from other equipment**."
    - It may be necessary to define separation distances instead of, or in addition to, the bonding at the entrance point. This is an alternative solution to multiple bonding. Simulation and tests should demonstrate this need. A typical case where this may be needed is when the bonding conductor is too long to be completely efficient. If the bonding conductor is short enough, there is no need for separation distance, except if the surge is coming from a metal part and not from the CSST. In that case, bonding between CSST and the metal part will do the same job. Alternatively, CSST specifically designed to have an enhanced lightning surge withstand may be used and should be included in the test program.

Note: It is also suggested to specifically include CSST in the NFIRS form, in order to have tools to validate in future that the provided solutions have been appropriate.

Annex 1: LIST OF CONTACTS IN THE USA

Some of contacts listed below have not yet replied. Some had no data to distribute that was relevant to the study. Others have provided data either belonging to their own study or from other sources, or have provided the name of another contact or provided comments relevant to the study. The data provided may not be relevant directly to our study, or may be relevant but be under a confidential clause. In this last case, data have been used as far as possible.

Name of contact	Entity
A Lorenz	State Fire Department - Montana
AC Daniels	State Fire Department - North Carolina
Anthony Morronne	Cozen O'Connor
Barry Gupton	State Fire Department - North Carolina
Beth Forshee	State Fire Department - Rhode Island
Blake Hayes	Fire Dpt - Zionville - Indiana
Bob Ballard	Intelligent Forensics
Bob Freeman	CSST incident witness
Bob Torbin	Omegaflex
Bob Torbin	OmegaFlex Inc
Brian Kraft	Rising Tide Consulting
Bruce Swiecicki	National Propane Gas Association
Bryan S. Bullock	State Fire Department - Delaware
Bud VanSickle	Lightning Protection Institute
Butch Browning	State Fire Department - Louisiana
Carol E Nolte	State Fire Department - West Virginia
Cheryl Karnowski	State Fire Department - Idaho
Chris Eckert	State Fire Department - New Jersey
Cindi Pitzer	State Fire Department - Ohio
Clarence J Leake	State Fire Department - West Virginia

Name of contact	Entity
Corporate	Allstate Insurance Company
Craig Barry	Smiths Heating Solutions Group
D May	Parker Hannifin Corporation
David D Brisco	Cozen O'Connor
Don Kunitomi	State Fire Department - California - Los Angeles
Douglas Fox	Cozen O'Connor
E Mann	State Fire Department - Pennsylvania
Edward J. Rupke	Lightning Technologies
Eric Hanson	Cozen O'Connor
EsayFlex	EsayFlex
Eve Domingcil	State Fire Department - Hawaï
George Chavez	State Fire Department - New Mexico
Ginny Capucci	State Fire Department - Nevada
Gretchen Dolan	Washington State Patrol
Hilda Garrett	State Fire Department - North Carolina
J Greeson	State Fire Department - Indiana
J Wood	State Fire Department - Vermont
James Wright	State Fire Department - Nevada
Joanie Schwartze	State Fire Department - Missouri
John Falgione	State Fire Department - Nebraska
John Hall	NFPA
John M. Tobias	U.S Department of the Army ElectroQuest
John Reich	State Fire Department - South Carolina
John Reis	Cozen O'Connor
John Skinner	CSA International
Judy Ruble	State Fire Department - Iowa
Julie Schrei	National Propane Gas Association
Kathleen Almand	Fire Protection Research Foundation
Keith McCarthy	State Fire Department - Florida
Kerri Fate	State Fire Department - Nebraska
Larry Barr	State Fire Department - Mississipi
Lawrence Wilson	Tru-Flex Metal Hose

Name of contact	Entity
Len Hathaway	CSST incident witness
Lindsey Williams	State Fire Department - Arkansas
Linro Gas Appliances	Linro Gas Appliances - New Zealand
Liz Brocker	State Fire Department - North Dakota
Loïs Vulgamore	Metal Fab Inc
Lori L Degristina	State Fire Department - Nevada
M Bigler	State Fire Department - Indiana
Marcos Hazan-Cohen	Cozen O'Connor
Mark Albino	Omegaflex
Mark Goodson	Goodson Engineering
Mark Harris	SGTE (Titeflex / Gastite)
Mark Larson	State Fire Department - Idaho
Mark Morgan	Lightning Safety Alliance
Marlinda Acevedo	State Fire Department - Colorado
Marty Ahrens	NFPA
Michael Johnston	National Electrical Contractors Association
Michael Stringfellow	PowerCET
Mitch Guthrie	Lightning Expert
Millicent K. Thompson	State Fire Department - Florida
Missy Lundberg	State Farm
NAHB	NAHB
Nancy L Olson	State Fire Department - West Virginia
Nazlee Aziz	State Fire Department - Florida
Nelson E Collins	State Fire Department - Maine
Office	US Fire Administration / NFRIS
Paul Linville	State Fire Department - New Mexico
Ray Hill	NEETRAC
Ray Shaun	Meta Fab Inc
Rebecca Kling	State Fire Department - Nevada
Reed E Cook	State Fire Department - West Virginia
Remington Brown	IBHS
Richard Hoffmann	Hoffmann & Feige

Name of contact	Entity
Richard Kithil	National Lightning Safety Institute (NLSI)
Richard Palmer	State Fire Department - Ohio
Richard Peddicord	State Fire Department - Kentucky
Robert Bailey	State Fire Department - Virginia
Robert Dahm	State Fire Department - Minnesota
Robert Doke	State Fire Department - Oklahoma
SF Dpt Office	Fire Department - Hawaï - Kaui
SF Dpt Office	Fire Department - Hawaï - Maui
SF Dpt Office	State Fire Department - Alabama
SF Dpt Office	State Fire Department - Alaska
SF Dpt Office	State Fire Department - Arizona
SF Dpt Office	State Fire Department - California
SF Dpt Office	State Fire Department - Connecticut
SF Dpt Office	State Fire Department - District of Columbia
SF Dpt Office	State Fire Department - Georgia
SF Dpt Office	State Fire Department - Guam
SF Dpt Office	State Fire Department - Hawaï
SF Dpt Office	State Fire Department - Illinois
SF Dpt Office	State Fire Department - Iowa
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SF Dpt Office	State Fire Department - Maryland
SF Dpt Office	State Fire Department - Michigan
SF Dpt Office	State Fire Department - Missouri
SF Dpt Office	State Fire Department - Nevada
SF Dpt Office	State Fire Department - New Hamphire
SF Dpt Office	State Fire Department - New York
SF Dpt Office	State Fire Department - North Dakota
SF Dpt Office	State Fire Department - Oregon
SF Dpt Office	State Fire Department - Rhode Island
SF Dpt Office	State Fire Department - South Dakota
SF Dpt Office	State Fire Department - Tennesee
SF Dpt Office	State Fire Department - Texas

Name of contact	Entity
SF Dpt Office	State Fire Department - Utah
SF Dpt Office	State Fire Department - Washington
SF Dpt Office	State Fire Department - Wisconsin
SF Dpt Office	State Fire Department - Wyoming
Shan Hood	SFCN (FlexTechGroup)
Stephen Coan	State Fire Department - Massachussets
Ted Lemoff	NFPA
Thomas Dunford	Cozen O'Connor
Thomas J Sullivan	Morgan Lewis
Tibor Egervary	Ward Manufacturing
Timothy Scanlan	Omegaflex
Wayne Goodwin	State Fire Department - North Carolina
William Rison	New Mexico Institute of Technology
	AHRI
	iii.org

Annex 2: REFERENCES

References sorted by name of file

Note: This list may contain fewer documents than studied or cited. Some private communication reports have been listed in order to be able to trace them, even if they cannot be accessed by the reader.

	Name of file	Title	Author	Date	Publisher
1	(New) Goodson CSST.pdf	Investigating The Causal Link Between Lightning Strikes, CSST, and Fire	Mark E Goodson, Mark Hergenrether	2005	
2	00736210.pdf	Some Observations on the Protection of Buildings Against the Induced Effects of Lightning	Eric Montandon, Marcos Rubinstein	1998	
3	1543- Home Structure Fires in Which Natural Gas or LP-Gas was Ignited by Lightning.pdf	Home Structure Fires in which Natural Gas or LP-Gas was Ignited by Lightning	Marty Ahrens	01/08/2010	NFPA
4	1553 - Home Lightning Gas Fires by Region, Area and Item.pdf	Home Structure Fires Caused by Lightning Ignitions of Natural or LP-Gas U.S. Region, Item First Ignited, and Area of Origin	Marty Ahrens	01/09/2010	NFPA

	Name of file	Title	Author	Date	Publisher
5	Void	Void	Void	Void	Void
6	2001 06 MetalFab Diamondback Specs L1808.pdf	Metal-Fab Inc - Corrugated Stainless Steel Tubing (CSST)	Metal-Fab Inc	2001	Metal-Fab, Inc
7	2001 Articles_Feature_Article_59b499d1aafc7010V.pdf	CSST: To Be or Not to Be	Eric Sticken	2001	Web
8	2001 TrainingGuide.pdf	Gastite The System Is The Solution – Training Guide	Titeflex Corp	2001	Titeflex Corp
9	2003 09 Code Acceptance.pdf	Model Code Acceptance	Titeflex Corp	2003	Titeflex Corp
10	2003 The CSST Battle Is Over.pdf	The CSST Battle Is Over - Plumbing and Mechanical	Kelly Faloon	2003	Web
11	2004 04 GastiteSpec15195.pdf	Gastite Product Specification	Titeflex Corp	2004	Titeflex Corp
12	2004 06 Omegaflex Lightning Safety Recs for GPS 06-2004.pdf	Lightning Safety Recommendations for Gas Piping Systems	OmegaFlex Inc	2004	OmegaFlex Inc
13	2005 01 Omegaflex TracPipe Installation Guide 01-2005.pdf	TracPipe - Design Guide and Installation Instruction	OmegaFlex Inc	2005	OmegaFlex Inc
14	2005 09 TruFlex Sales sm tri fold ProFlex.pdf	The Future in Gas Piping Systems for Today and Tomorrow	Tru-Flex Metal Hose Corp	2005	Tru-Flex Metal Hose Corp
15	2006 01 Wardflex IG 01-2006.pdf	Wardflex Design and Installation Guide	Ward Manufacturing Company	2006	Ward Manufacturing Company
16	2006 01Gastite Move Plant.pdf	Flexible Solutions	Titeflex Corp	2006	Titeflex Corp
17	2006 03 ASTM_E-84_ComplianceReport.pdf	Report no. 3094185CRT-001	Intertek ETL Semko	2006	Intertek Etl Semko
18	2006 08 Gastite Electrical Bonding and Grounding 08-2006.pdf	Technical Bulletin #TB2006-04	Titeflex Corp	2006	Titeflex Corp

	Name of file	Title	Author	Date	Publisher
19	2006 11 Omegaflex Letter to customers.pdf	CSST Class Action Lawsuit Settlement	OmegaFlex Inc	2006	Web
20	2006 11 Wardflex Electrical Bonding and Grounding 16.pdf	Technical Bulletin #16	Ward Manufacturing Company	2006	Ward Manufacturing Company
21	2006 Gastite Underground Installation Guide.pdf	Underground Gas Polyethylene (PE) Piping – Installation Guide	Titeflex Corp	2006	Titeflex Corp
22	2006 Installation Guide Gastite.pdf	Design and Installation Guide	Titeflex Corp	2006	Titeflex Corp
23	2006 Tru-Flex-Bulletin.pdf	Technical Bulletin 112006 Electrical Bonding and Grounding	Tru-Flex Metal Hose Corp	2006	Tru-Flex Metal Hose Corp
24	2007 01 TB2007_01.pdf	Technical Bulletin #TB2007-01	Titeflex Corp	2007	Titeflex Corp
25	2007 03 MetalFab Electrical Bonding & Grounding L2439.pdf	Technical Bulletin #TB8029-07	Metal-Fab Inc	2007	Metal-Fab, Inc
26	2007 03 Omegaflex TracPipe IG Michigan 03-2007.pdf	TracPipe - Design Guide and Installation Instruction	OmegaFlex Inc	2007	OmegaFlex Inc
27	2007 09 Parker Parflex IG.pdf	Design and Installation Guide – Section 4.0	Parker Hannifin Corporation	2007	Parker Hannifin Corporation
28	2007 Gastite 2009 NFGC.pdf	2009 NFGC to include CSST Bonding Language	Titeflex Corp	2007	Titeflex Corp
29	2007 Gastite_Installation_Instructions.pdf	Design and Installation Guide	Titeflex Corp	2007	Titeflex Corp
30	2007 WardFlex FAQs.pdf	FAQs	Ward Manufacturing Company	2007	Ward Manufacturing Company
31	2007-2008 North Dakota Fires.pdf	2007-2008 North Dakota Fires	North Dakota State Fire Marshal	2008	North Dakota State Fire Marshal

	Name of file	Title	Author	Date	Publisher
32	2008 07 Pro-Flex_install.pdf	Installation/Training Guide	Tru-Flex Metal Hose Corp	2008	Tru-Flex Metal Hose Corp
33	2008 08 Omegaflex Lightning Safety Recs for GPS 08-2008.pdf	Lightning Safety Recommendations for Gas Piping Systems	OmegaFlex Inc	2008	OmegaFlex Inc
34	2008 09 PersonnelNews.pdf	Change Within the Management Team	Ward Manufacturing Company	2008	Ward Manufacturing Company
35	2008 09 Technical_Bulletin_WF2008.pdf	Technical Bulletin: # WF2008-1 Wardflex® CSST Electrical Bonding	Ward Manufacturing Company	2008	Ward Manufacturing Company
36	2008 11 __www.wardflex.com_bonding_faq.pdf	FAQs	Ward Manufacturing Company	2008	Ward Manufacturing Company
37	2008 11 Gastite Routing TB2008_02.pdf	Technical Bulletin TB2008-02	Titeflex Corp	2008	Titeflex Corp
38	2008 11 Gastite_LightningSafety_HomeOwner.pdf	Important Gastite Lightning Safety Warning	Titeflex Corp	2008	Titeflex Corp
39	2008 Gastite_Installation_Instructions.pdf	Design and Installation Guide	Titeflex Corp	2008	Titeflex Corp
40	2008 TruFlex Electrical-17648.pdf	Electrical Bonding – Pro Flex CSST – July 2008	Tru-Flex Metal Hose Corp	2008	Tru-Flex Metal Hose Corp
41	2009 02 Mass Consumer Affairs 02-2009.pdf	Regarding Corrugated Stainless Steel Tubing (CSST)	Consumer Affairs and Business Regulation	2009	Web
42	2009 06 Omegaflex TracPipe IG 06-2009.pdf	TracPipe - Design Guide and Installation Instruction	OmegaFlex Inc	2009	OmegaFlex Inc
43	2009 06 WARDFLEX_D&I_GUIDE_Eng.pdf	Design and Installation Guide	Ward Manufacturing Company	2009	Ward Manufacturing Company

	Name of file	Title	Author	Date	Publisher
44	2009 06 WARDFLEX_D&I_GUIDE_FR_lo.pdf	Guide de Conception et d'Installation	Ward Manufacturing Company	2009	Ward Manufacturing Company
45	2009 07 NH TechnicalBulletinonCSST7-16-09.pdf	Technical Bulletin and Application of the Code on CSST	State of New Hampshire Department of Safety	2009	Web
46	2009 09 17482_TF_TrainingG15.pdf	Installation/Training Guide PRO-FLEX® CSST	Tru-Flex Metal Hose Corp	2009	Tru-Flex Metal Hose Corp
47	2009 09 Indiana proposed code change 2009.pdf	Proposed Code Change	Indiana Department of Homeland Security	2009	Web
48	2009 10 MetalFab IG GB L1627 10-09 Chapter 4-10.pdf	Design and Installation Guide - Chapter 4-10	Metal-Fab Inc	2009	Metal-Fab Inc
49	2009 10 MetalFab IG GB L1627 10-09.pdf	Design and Installation Guide	Metal-Fab Inc	2009	Metal-Fab Inc
50	2009 10 Spanish_WF_Bonding_Tech2008_ES.pdf	Technical Bulletin: # WF2008-1 Wardflex® CSST Electrical Bonding in Spanish	Ward Manufacturing Company	2009	Ward Manufacturing Company
51	2009 11 CSA csalisting.pdf	Certificate of Compliance	Metal-Fab Inc	2009	Metal-Fab Inc
52	2009 Form586.pdf	Wardflex® Design and Installation Guide : Sizing Charts A-2	Ward Manufacturing Company	2009	Ward Manufacturing Company
53	2010 03 Mtlfab Diamondback L1626.pdf	Catalog	Metal-Fab Inc	2010	Metal-Fab Inc
54	2010 06 TB2010-01.pdf	Technical Bulletin #TB2010-01	Titeflex Corp	2010	Titeflex Corp
55	2010 08 D+I_Guide_August2010.pdf	Design and Installation Guide	Titeflex Corp	2010	Titeflex Corp

	Name of file	Title	Author	Date	Publisher
56	2010 10 Cozen CSST Omegaflex.pdf	Jury rules that CSST is a defective product in Landmark case	Cozen O'Connor	2010	Cozen O'Connor
57	2010 Form593_R.pdf	Wardflex® Design and Installation Guide : Sizing Charts A-1 & A-4	Ward Manufacturing Company	2010	Ward Manufacturing Company
58	54-A2005-ROC	Report on Comments — NFPA 54 Report of the Committee on National Fuel Gas Code	NFPA	2005	NFPA
59	54-A2005-ROP.pdf	Report on Proposals — NFPA 54 Report of the Committee on National Fuel Gas Code	NFPA	2005	NFPA
60	54-A2008-ROC.pdf	Report on Comments — NFPA 54 A compilation of NFPA® Technical Committee Reports on Comments for the 2008 Annual Revision Cycle	NFPA	2008	NFPA
61	54-A2008-ROP.pdf	Report on Proposals — NFPA 54, A compilation of NFPA Technical Committee Reports on Proposals for Public Review and Comment	NFPA	2008	NFPA
62	62305-1e-ed1.pdf	INTERNATIONAL ELECTROTECHNICAL COMMISSION PROTECTION AGAINST LIGHTNING – Part 1: General Principles	IEC	2006	IEC
63	62305-2e-ed1.pdf	INTERNATIONAL ELECTROTECHNICAL COMMISSION PROTECTION AGAINST LIGHTNING – Part 2: Risk Assesment	IEC	2006	IEC
64	62305-4e-ed1.pdf	INTERNATIONAL ELECTROTECHNICAL COMMISSION PROTECTION AGAINST LIGHTNING – Part 4 Electrical and Electronic Systems within Structures	IEC	2006	IEC

	Name of file	Title	Author	Date	Publisher
65	American Gas Association FACTSHEETGasPipingBondingDecember102009.pdf	ELECTRICAL BONDING OF GAS PIPING SYSTEMS	AGA	December 2009	
66	ANSI-LC1-2005-CSA6-26-2005.pdf	American National Standard/ CSA Standard for Fuel Gas Piping Systems Using Corrugated Stainless Steel Tubing (CSST)	ANSI/CSA	2005	ANSI
67	Article Cozen 1.pdf	CLAIMANT BEWARE: Construction Defects to Real Property: Georgia's Statute of Repose v. Statute of Limitations	Cozen O'Connor	2009	Cozen O'Connor
68	Article Cozen 14 July 2009.pdf	Summer Storms and Lightning CSST Fires	Cozen O'Connor	2010	Cozen O'Connor
69	Article Cozen 29 July 2010.pdf	NFPA Reviewing Safety of CSST	Cozen O'Connor	2010	Cozen O'Connor
70	AttachA_Final_Bonding DI Guide.doc	Electrical Bonding of CSST Systems	Cutting Edge Solutions	September 2008	
71	Bonding Effectiveness Aug 2007.pdf	Effectiveness of Direct Bonding of Gas Piping in Mitigating Damage from an Indirect Lightning Flash	Brian Kraft, Robert Torbin	August 2007	
72	Bonding Metal Gas Piping _ IAEI Magazine Online.htm	Bonding Metal Gas Piping	Michael Johnston	July 2009	
73	CCH 2007_01_Kits PLT_06 2007.pdf	Book of Specifications for CSST - France	AFG	2007	AFG
74	Code Approval Gastite.pdf	Code Approvals	Titeflex Corp	-	Titeflex Corp
75	ConcealedFittings.pdf	Interpretive Response - Concealed fittings	Titeflex Corp	2001	Titeflex Corp
76	Connector-with-Termination-Plate-Photo.jpg	Picture	Tru-Flex Metal Hose Corp	-	Tru-Flex Metal Hose Corp

	Name of file	Title	Author	Date	Publisher
77	Cozen CSST-TF_brochure.pdf	Field Adjuster's Handbook	Cozen O'Connor	-	Cozen O'Connor
78	Cozen Subrogation and Recovery.pdf	Cozen Subrogation and Recovery	Cozen O'Connor	2010	Cozen O'Connor
79	CSST 1.pdf	Fire Risks Involving Corrugated Stainless Steel Tubing (CSST) Gas Lines and Lightning Strikes	Daniel Snyder	-	Web
80	CSST ABC News 10-2007.pdf	Common Gas Pipes Pose Fire Hazard	abc	16/10/2007	Web
81	CSST NY 04-2010.pdf	Corrugated Stainless Steel Tubing (CSST)	NY State Fire Prevention and Building Code Council	2010	Web
82	CSST Article Cozen 29 July 2010.pdf.pdf	NFPA Reviewing Safety of CSST	Anthony Morrone	July 29, 2010	Cozen O'Connor
83	CSST Task Force.pdf	CSST Task Force	Cozen O'Connor	2010	Cozen O'Connor
84	csst_lightningconcerns.pdf	Corrugated Stainless Steel Tubing for Fuel Gas Distribution in Buildings and Concerns over Lightning Strikes	NAHB	August 2007	NAHB
85	CSST_policyreq.pdf	Corrugated Stainless Steel Tubing Policy Requirements	We energies		We energies
86	csst_updates.pdf	CSST Settlement - Recent Updates	Circuit Court of Clark County	2007	Circuit Court of Clark County
87	CSST-DANGERS.pdf	Investigating the Causal Link between Lightning Strikes, CSST and Fire	Mark Goodson PE		Web

	Name of file	Title	Author	Date	Publisher
88	CSST-Gas-Pipe-Class-Action TEXAS.pdf	CSST Gas Pipe Material Class Action Settlement	Texas Real Estate Commission	-	Web
80	csstlightning (2).docx	Is There a Lightning Induced Fire Hazard in Bedford?	Clive Kimblin	16/09/2010	Private communication
90	DE95016094[1].pdf	Reliable Simulation of Metal Surface Penetration by Lightning Continuing Currents	W. Zischanck, F. Drumm	1995	
91	EasyFlex Contacts.pdf	EasyFlex Contacts	EasyFlex	2010	EasyFlex
92	EasyFlex Installation.pdf	EasyFlex - Installation Leaflet	Kofulso	2010	Kofulso
93	ES-CSST.pdf	Flexible Gas Tubing/CSST	Titeflex Corp	2010	Titeflex Corp
94	Ex.2.CSA.pdf	Stipulation and Settlement Agreement	Circuit Court of Clark County	2007	Circuit Court of Clark County
95	FRISCO Gas pipe ban.pdf	Frisco Bans Pipes Used in New Homes	Stella M Chavez	2003	The Dallas Morning News
96	Gas Line a Factor in Fire that Destroyed HomeABC News 4.mht	Gas Line a Factor in Fire that Destroyed Home	ABC news	20/07/2009	ABC news
97	Gas-Appliance-Kit-Photo.jpg	Picture	Tru-Flex Metal Hose Corp	-	Tru-Flex Metal Hose Corp
98	Gastite CSST 2.pdf	Corrugated Stainless Steel Tubing	Titeflex Corp	-	Titeflex Corp
99	Gastite_Preview_6-4-09.wmv	Video	Titeflex Corp	2009	Titeflex Corp
100	Gazpoz - Russia catalog_item479.pdf	EasyFlex - Russia	Kofulso	2010	Kofulso

	Name of file	Title	Author	Date	Publisher
101	GE paper Effect of lightning on thin metal surfaces.pdf	Effect of Lightning on Thin Metal Surfaces	K.B. McEachron; J.H.Hagenguth	1942	
102	Guide d'installation TracPipe Banides.pdf	Tracpipe France – Installation Guide	Banides et Debeaurain	-	Banides et Debeaurain
103	History.pdf	Metal-Fab Inc. Presentation and History	Metal-Fab Inc	2003	Metal-Fab Inc
104	Indiana Fires.pdf	Finding the Fire	Bob Segall	2008	Web
105	Interlock-Photo.jpg	Picture	Tru-Flex Metal Hose Corp	-	Tru-Flex Metal Hose Corp
106	JLightConstrJuly2004.pdf	New Lightning-Resistant Flexible Gas Line Shines During Demonstration	IN THE NEWS" magazine	July 2004	
107	Kofulso - Kazakhstan.pdf	EasyFlex - Kazakhstan	Kofulso	2010	Kofulso
108	KOFULSO-CO-LTD.pdf	Kofulso - South Korea	Kofulso	2010	Kofulso
109	Kofulso-olton - Russia.pdf	EasyFlex - Russia	Kofulso	2010	Kofulso
110	Kofuslo - Russia.pdf	EasyFlex - Russia	Kofulso	2010	Kofulso
111	Lightning overvoltages in wires within the buildings.pdf	Lightning Overvoltages in Wires within the Buildings	Andrzej Sowa		
112	Lightning Related Issues.doc	Fire Risks Involving CSST Gas Lines and Lightening Strikes	Factoidz.com	2010	Web
113	LightningProtectionLH07072007.pdf	Lightning Protection	Len Hathaway		Web
114	Lovelis Titeflex	Lovelis, et al. v. Titeflex Corp., Inc., et al	Wikinvest.com	2009	Web

	Name of file	Title	Author	Date	Publisher
115	LPS CSST GAS PIPE LIGHTNING EXPERIENCE.doc	CSST GAS PIPE LIGHTNING EXPERIENCE	Private Communication	June 23, 2010	
116	LPS CSST Incident May 2007.docx	CSST Lightning Incident	Private Communication	October 6, 2010	
117	Manifold-Hookup-Photo.jpg	Picture	Tru-Flex Metal Hose Corp	-	Tru-Flex Metal Hose Corp
118	Mechanical, lightning groups at odds over CSST.pdf	Mechanical, Lightning Groups at Odds over CSST	Brian Wasag	-	Web
119	Midwest2008.pdf	Improperly Installed Gas Lines Pose Fire Hazard to Indiana Homes	Insurance journal	7 september 2008	
120	NAHB CSST Toolbase.pdf	Corrugated Stainless Steel Tubing (CSST) for Gas Distribution	NAHB Research center	2003	Web
121	NEC_Lightning_Report-rev2.pdf	Evaluation of CSST Gas Piping Subjected to Electrical Insult	Brian Kraft, Robert Torbin	October 2009	
122	NewBondingClamp5-28-08.pdf	New Bonding Clamp	Ward Manufacturing Company	2008	Ward Manufacturing Company
123	NF DTU 61.1 P2.pdf	Gas Installation in Residential Structures – Part 2	AFNOR	2006	Banides et Debeaurain
124	NFPANews0309.pdf	Report on Comments — Comments Sought Proposed Tentative Interim Amendments	NFPA	39873	NFPA News

	Name of file	Title	Author	Date	Publisher
125	p379 Goodson Gasline and Lightning .pdf	LIGHTNING INDUCED CSST FIRES / FIRE AND MATERIALS 2005 31st January - 1st February 2005 Fisherman's Wharf, San Francisco USA	Mark E Goodson, Mark Hergenrether	1st February 2005	Interscience Communications FIRE AND MATERIALS 2005 31st January - 1st February 2005 Fisherman's Wharf, San Francisco USA
126	Parflex 4660PGP_Specification Sheet.pdf	Product Specifications	Parker Hannifin Corporation	-	Parker Hannifin Corporation
127	Parkflex Bulletin.pdf	Parker Hannifin Corporation - Parflex Division	Parker Hannifin Corporation	-	Parker Hannifin Corporation
128	Pilotte Fire Report.pdf	Division of Fire Safety Fire Investigations REPORT OF FIRE INVESTIGATION	Frederick J. Sumpter, IAAI-CFI	18/09/2006	
129	PlumbingEngineerSeptember2010.doc	CSST System Advancements Take Aim at Lightning Safety	Plumbing Engineer September Issue 2010 Craig Barry	September 2010	
130	ProFlex Fixing Assembly.pdf	ProFlex CSST - Fixing Assembly	Tru-Flex Metal Hose Corp	-	Tru-Flex Metal Hose Corp
131	Royal Metal - Jay Moon - Mail.pdf	Mail from Royal Metal - South Korea	Royal Metal Inc	2010	Royal Metal Inc
132	SEFTIM Response.docx	Technical, Demographic, and Institutional Issues Affecting the Bonding of CSST Systems	Bob Torbin	1/10/2010	Bob Torbin

	Name of file	Title	Author	Date	Publisher
133	standards council decision.pdf	SC #10-3-20 D#10-2	NFPA	23 June 2010	NFPA
134	The wholesaler - March 2009.pdf	In Less than Two Decades,Gastite Establishes Strong Position in Market	Mary Jo Martin	2009	The Wholesaler
135	Titeflex_electrical_box_tag.pdf	Gastite Installer: Affix this tag to electrical box	Titeflex Corp	2007	Titeflex Corp
136	Titeflex_spool_sticker.pdf	Warning	Titeflex Corp	2007	Titeflex Corp
137	TracPipe CSST Installation Manual 111743_Omega_Flex.pdf	FLEXIBLE GAS PIPING DESIGN GUIDE	Omega Flex	June 2009	Omega Flex
138	USFA Fire in the US 2003-2007 fa_325.pdf	Fire in the United States 2003-2007	FEMA	2010	FEMA
139	USFA Profile of Fire in the US 2003-2007 profile_fitus_15th.pdf	A Profile of Fire in the United States 2003-2007	U.S. Fire Administration/National Fire Data Center	2010	U.S. Fire Administration/National Fire Data Center
140	WARD Fitting News ReleaseR.pdf	News Release - New Fitting Connects Wardflex® in less time, every time.	Ward Manufacturing Company	-	Ward Manufacturing Company
141	Wardflex Tags.pdf	Wardflex® Information Card	Ward Manufacturing Company	2007	Ward Manufacturing Company
142	wardflex_bonding_grounding_faq.pdf	Bonding and Grounding FAQs	Ward Manufacturing Company	-	Ward Manufacturing Company
143	WARDFLEX_CutAway.jpg	Picture	Ward Manufacturing Company	-	Ward Manufacturing Company
144	WardflexBrochureWeb.pdf	Flexibility. Simple as That.	Ward Manufacturing Company	-	Ward Manufacturing Company

	Name of file	Title	Author	Date	Publisher
145	WardflexforWeb_FR.pdf	Fléxibilité. Aussi simple que ça.	Ward Manufacturing Company	-	Ward Manufacturing Company
146	WARDFLEXphoto.jpg	Picture	Ward Manufacturing Company	-	Ward Manufacturing Company
147	warning_tag.pdf	Wardflex® Information Card	Ward Manufacturing Company	-	Ward Manufacturing Company
148	Foster-Miller report.pdf	Protection of Residential Housing from the Effects of Direct and Indirect Lightning Strikes	FOSTER-MILLER	DECEMBER 2002	
149	CSST Gas Line Bonding - BCW.ppt	CSST Gas Line Bonding Because Fire Never Read the Rule Book!	National Association of commercial building inspectors and thermographers Compiled by Bill Warne	2008	Web
150	2008 02 001 Mechanical, lightning groups at odds over CSST.pdf	Mechanical, Lightning Groups at Odds over CSST	Contractormag.com	Feb 1, 2008	Web
151	Cozen CCST.pdf	Origin and Cause	Cozen O'Connor	-	Cozen O'Connor
152	100929 Parker Parflex Hannifin.pdf	Mail from Parker Hannifin Corporation	Parker Hannifin Corporation	2010	Parker Hannifin Corporation

	Name of file	Title	Author	Date	Publisher
153	2009 09 TruFlex Electrical-17479.pdf	Electrical Bonding - Pro-Flex CSST	Tru-Flex Metal Hose Corp	2009	Tru-Flex Metal Hose Corp

Annex 3: SOME ANNOTATED INCIDENTS

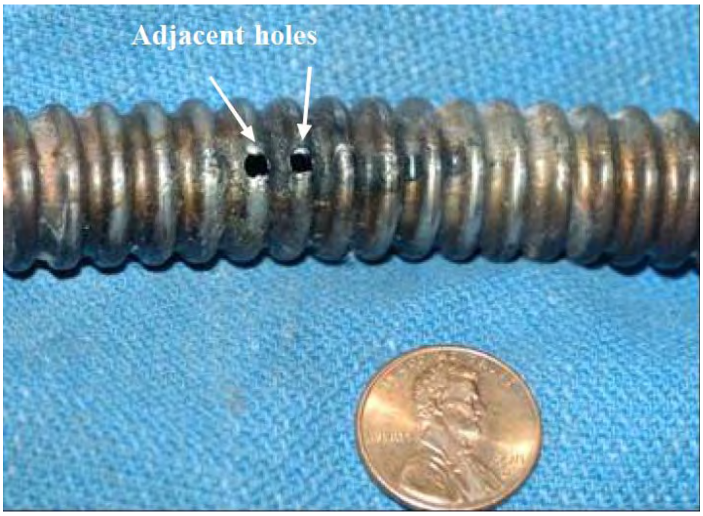
The number of documented incidents for which we have (more or less) detailed data is currently far too small to derive from it any pertinent statistics or even trends. For most of the incidents, many parameters are missing, especially those related to CSST bonding (such as quality of bonding or even presence of bonding).

Also we are aware of three detailed cases where damages occurred on black pipe or flexible appliance connectors.

In order to be able to compare these annotated incidents with the list of 141 incidents discussed in section 4.1.1.4, we give for each of the cases, when available, information regarding whether it was a direct strike or not, whether the CSST installation was bonded or not, whether an electrical circuit or appliance was involved or not (*involved* here means that the electrical circuit or appliance has been damaged. It does not mean that electrical circuit is the cause of CSST damage).

A3.1 Place of event: ? / Date of event: < October, 2004

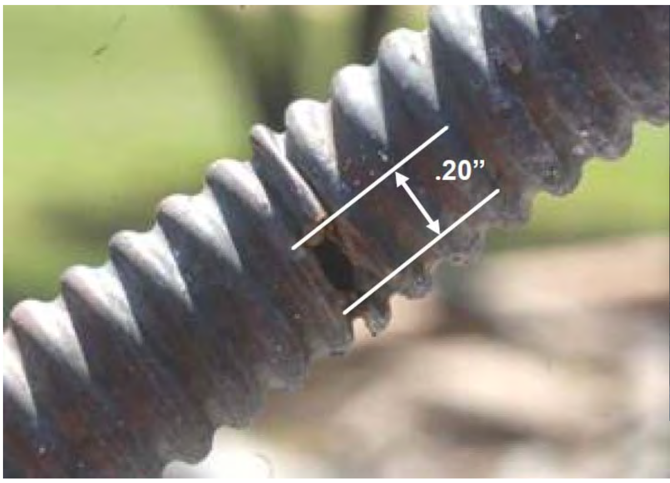
Name of file:	p379 Goodson gasline and lightning .pdf
Title:	LIGHTNING INDUCED CSST FIRES/FIRE AND MATERIALS 2005 31st January - 1st February 2005 Fisherman's Wharf, San Francisco USA
Author:	Mark E Goodson
Date of publication:	February 1, 2005
Place of event:	?
Date of event:	< October, 2004
Direct strike?	?
CSST bonded?	?
Electrical lines involved?	?
Comment	Good example of multiple holes on CSST.



Detailed investigation:	The fire occurred in the wood framed chimney space that had a metal chimney insert. CSST ran through the chimney space to feed the gas igniter. **Four** perforations were found in the CSST, ranging in size from a pinhole to a hole about 125 mils along its major axis. A lightning report showed that 4 hits within 0.1 mile of the house were recorded.

A3.2 Place of event: Edmond, Oklahoma / Date of event: < October, 2004

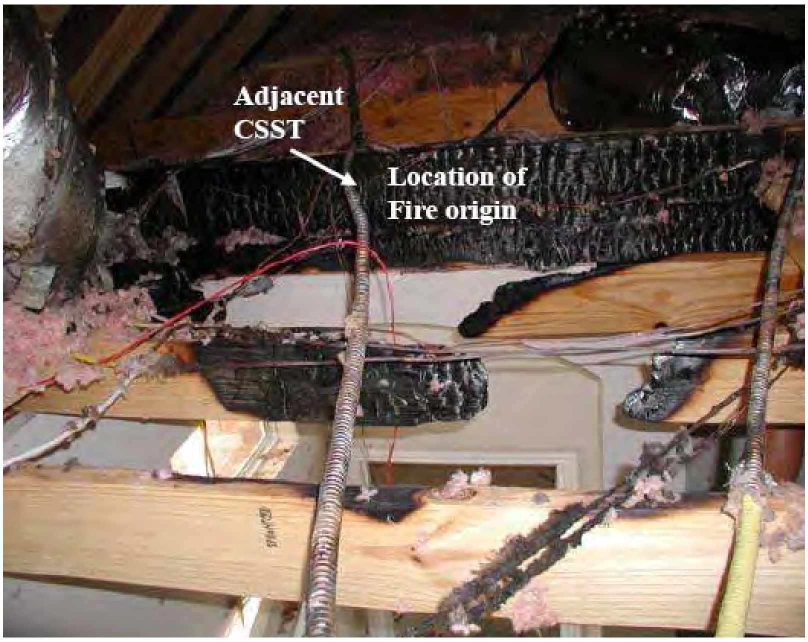
Name of file:	p379 Goodson gasline and lightning .pdf
Title:	LIGHTNING INDUCED CSST FIRES/FIRE AND MATERIALS 2005 31st January - 1st February 2005 Fisherman's Wharf, San Francisco USA
Author:	Mark E Goodson
Date of publication:	February 1, 2005
Place of event:	Edmond, Oklahoma
Date of event:	< October, 2004
Direct strike?	?
CSST bonded?	?
Electrical lines involved?	Apparently not
Comment	No details



Detailed investigation:	The fire occurred in (construction not finished) a 2 story house, and plumbed with approximately 95% black pipe. Two runs of CSST, each serving a fireplace, comprised the CSST piping in the house. A perforation with its major axis measuring approximately 200 mils was found in one run of the CSST. An interview with a neighbor confirmed that the audible and visual components of the strike were sensed simultaneously. A positive lightning report was obtained, showing 11 strikes within 0.5 mile. Regrettably, the house was razed before the investigation was complete.

A3.3 Place of event: Cedar Hill, Texas / Date of event: ?

Name of file:	(New) Goodson CSST.pdf
Title:	Investigating the Causal Link between Lightning Strikes, CSST, and Fire
Author:	Mark E Goodson
Date of publication:	2005
Place of event:	Cedar Hill, Texas
Date of event:	?
Direct strike?	?
CSST bonded?	?
Electrical lines involved?	?
Comment	No details



Detailed investigation:	The fire occurred within the attic space of a home, which included several runs of CSST. The CSST runs went to a fireplace, furnace, range, and water heater. During a lightning storm, the CSST run serving the fireplace leaked and the resultant fire then destroyed a section of the attic. A perforation measuring 95 mils along its major diameter was found in the pipe. A lightning report showed that there were approximately 5 strikes within 0.3 mile of the house. The fire was contained within the attic, but subjected the house to extensive smoke damage.

A3.4 Place of event: Raleigh, North Carolina / Date of event: July 20, 2010

Name of the file:	csstlightning (2).docx + private communication
Title:	Is There a Lightning Induced Fire Hazard In Bedford?
Author:	Multiple authors including Mitch Guthrie
Date of publication:	September 16, 2010
Place of event:	Raleigh, North Carolina
Date of event:	July 20t, 2010, at about 7:00pm
Direct strike?	Yes
CSST bonded?	Yes
Electrical lines involved?	No
Comment	Multiple holes from direct lightning.

Detailed

investigation:

Bedfordtown, Raleigh, NC is a residential community of houses with protruding vents connected to gas water heaters supplied via corrugated stainless steel tubing (CSST) at ground potential.

In Bedford all of the houses have vents protruding from the roofs. If lightning hits a vent that is solely connected to a gas water heater, the current will go to ground through a metal path that includes the CSST (corrugated stainless steel tubing) flexible gas pipe that feeds the gas water heater. This CSST is usually grounded as it enters the house (at a distance of several tens of feet from the heater). In the event of a direct hit the current has to pass along the thin metal wall of the gas pipe before it finally goes to ground

July 20th, 2010, at about 7:00pm, the house at 10408 Bedfordtown Drive was hit directly by lightning. The resulting fire caused losses exceeding $150K and great family disruption. Fortunately no one was injured.

The fire investigator suspects that lightning hit the gas vent connected to the gas water heater and went to ground via the CSST gas pipe. He suspects that the high current pulse caused holes to form in the tubing and that the gas ignited. Here it is noted that the run of CSST, from entering the house to the third floor water heater, has a length exceeding fifty feet.

The property uses PVC piping for the water system. Compared to the copper pipes of older homes, PVC pipes do not provide an additional conducting path from the gas water heater to ground.

There had been an electrical power outage in area of Bedford about 15 minutes before the lightning strike and that there was still no electricity at the time of the lightning strike. Thus a fire of electrical origin can be ruled out.

Report from the news: "Raleigh, N.C. — Fire investigators said lightning is to blame for two house fires in Raleigh Tuesday evening. A two-story home at 5219 Coffeetree Drive caught on fire at about 6:30 p.m. Part of the roof and attic were damaged by the flames. No one was injured. Lightning is also thought to have caused a fire at 10408 Bedfordtown Drive in Raleigh at about 7:30 p.m. The home suffered roof and water damage. Four people were inside the home at the time of the fire but no one was injured."

The NFIRS report doesn't mention CSST.

Mitch Guthrie indicates that a Strike Fax report procured for the date of the incident revealed a lightning strike of -12.3 kA within 0.0 miles of the structure. The most likely attachment point for the structure was the vent pipe for the hot water heater. This is justified by the location of the vent pipe on the edge of the roof of the structure being a prominent streamer production location and the fact that immediately below this vent pipe was the location of the initial fire found by the homeowner. There was no other direct conductive route between the water heater vent and ground except through CSST connections to the gas dryer on one side and gas furnace on the other. According to the homeowners, there was some apparent fusing at screws connecting the vent pipe to the water heater at the top and between the feet and a metal catch pan at the bottom of the water heater. Two damaged sections of CSST had been removed by the insurance company but the homeowner said both had multiple holes: one running between the water heater and the furnace (approximately 13 feet long with around 10 holes) and the other one running from the water heater to the dryer(approximately 18 feet long with around 15 holes).

Probable Striking Point

As discussed in the main text, the fact that there are multiple holes cannot be explained by a single flashover between CSST and a metallic part or conductor. As a matter of fact, a sparkover immediately led to a voltage drop, which made sparkover less likely at another place. This is a well known occurrence on power lines where the weakest part sparks over first, and this then protects the downstream circuits from another sparkover. The only possibility for multiple sparkover points to occur would be if the voltage after sparkover remained so large that another sparkover could occur somewhere else, but in that case we could expect one or two more flashovers and not 10 to 15, especially so close to each other. The explanation for such multiple holes can only be related to a direct strike current and to the particular behavior of CSST under direct lightning strikes.

A3.5 Place of event: Menomonee Falls, Wisconsin / Date of event: November 5, 2005

Name of file:	CSST ABC News 10-2007.pdf
Title:	Common Gas Pipes Pose Fire Hazard
Author:	ABC
Date of publication:	October 16, 2007
Place of event:	Menomonee Falls, Wisconsin
Date of event:	November 5, 2005
Direct strike?	?
CSST bonded?	?
Electrical lines involved?	?
Comment	No details

Detailed investigation:

The fire was linked to CSST and the Hoods weren't the only ones in town who found out the hard way about the dangers of the piping.

"We had three fires in four months in this neighborhood. All were a direct result of lightning strike and CSST," said Lt. Maxwell Brunner of the Menomonee Falls Fire Department.

The day this story aired lightning struck my home or near my home and I had a gas leak in my CSST. At this time I was two weeks away from being in my home one year. Only by the grace of God my house didn't explode and catch on fire. I was out of the country at the time, but my Mom and two boys were home asleep while gas was leaking into my home. The makers of the CSST state that "when properly installed" it works. My CSST isn't installed properly. I do not want CSST in my home weather it's properly installed or not. This is a dangerous product. I will never buy another home with CSST in it.
(angsboy 12/3/07)

I was unfortunate enough to have suffered a major fire this past June due to the rupture of CSST in my PA home. The house was less than two years old. The night of the fire, there was a terrible storm. Lightning struck a tree some 40 feet from the house. A copper water line near the tree ran into the house just inches below the CSST which connected to a copper tube exiting the house and connecting to my propane tank.

The energy ruptures the CSST and the ensuing fire severely damaged the house. We are now in the process of tearing down the remaining structure and rebuilding. CSST is a dangerous product. The fire inspector said that even with lightning arrestors we would not have been saved. This is a dangerous product and the CPSC should ban its use in homes.

(artsussman 10/22/07)

A3.6 Place of event: Central Indiana / Date of event: < September, 2008

Name of file:	Midwest2008.pdf
Title:	Improperly Installed Gas Lines Pose Fire Hazard to Indiana Homes
Author:	Insurance journal
Date of publication:	September 7, 2008
Place of event:	Central Indiana
Date of event:	< September, 2008
Direct strike?	?
CSST bonded?	?
Electrical lines involved?	?
Comment	No details


Note: Pictures are taken from another Indiana article. They may not relate to the same case.

Detailed

investigation:

The *Indianapolis Star* reported.

At least 35 homes in Boone, Hamilton, and northern Marion counties have burst into flames in the past five years after newer lines made of the tubing were breached by lightning, the newspaper said.

Fishers Fire Chief Brian Lott is so concerned about such fires that he plans to lobby state lawmakers in their upcoming session to ban the use of corrugated stainless steel tubing, also known as CSST.

Half of the lightning related fires fought by the Fishers department can be traced to damaged CSST, said spokesman Ron Lipps.

The state has twice revised its building codes since 2005 to make new homes safer, but those changes apply only to new homes and not to thousands of homes built before the code changes.

"In 2007, electricity from a lightning strike melted a hole in a gas line in Coby Maxwell's Zionsville home, starting a fire in his basement. Repairmen have since replaced the damaged CSST lines, but Maxwell fears it could happen again."

When interviewed Omegaflex declared: "We found, after looking around, that some people don't do that," … "When they do install it correctly, we haven't found any problems at all."

In 2005, Indiana changed its code for new homes to require bonding and grounding procedures. Then, in April, Indiana officials revised the code to require at least a 2-inch gap between the CSST and any other kind of metal to prevent arcing, which can cause a fire.

Other examples from Indiana:

A house earlier this summer had a lightning strike. For some reason the gas line became a conductor and it developed pinholes nearly the entire length of the house. It did not explode, but it didn't really make a difference since the house was a total loss, explosion or not.

This past weekend my 20 year old daughter was house-sitting for a friend, she called me just after a thunderstorm had gone through and said that she smelled something burning in the basement. I went over to check it out and found the gas line burning behind the drywall in a bulkhead. There were several wires in the bulkhead also. The fire was next to a joist and had been burning for at least 40 minutes by the time I got there. This was located in the middle of the house.

We had our house built about 8 years ago, and last week it burned to the ground. A tree in our backyard was struck by lightning and a feeder from that hit the roof of our house. The feeder struck the gas line (which was magnetized by CSST), and the gas line served as a blow torch and totally burnt our house. We had 4000 square feet, and we lost everything

A3.7 Place of event: Mount Pleasant, South Carolina / Date of event: July 16, 2009

Name of file:	Gas Line a Factor in Fire that Destroyed HomeABC News 4.mht + private communication
Title:	Gas Line a Factor in Fire that Destroyed Home
Author:	ABC news + Mitch Guthrie
Date of publication:	July 20, 2009
Place of event:	Mount Pleasant, South Carolina
Date of event:	July 16, 2009
Direct strike?	Yes
CSST bonded?	Yes
Electrical lines involved?	Possible as the fire occurred as a result of a hole in CSST near a gas fireplace
Comment	Direct lightning strike. Damage in spite of bonding.

Detailed investigation:

The owners of a home in Rivertowne are moving out after their house was hit by lightning on Thursday.

Mount Pleasant fire officials tell us that that home might not have caught fire had its gas line been installed differently.

Mount Pleasant fire inspectors believe lightning traveled into the home's gas line, one made out of corrugated stainless steel tubing, better known as CSST.

"From what we've seen, lightning super heats the pipe, a pinhole may pop out in the pipe…the gas comes out, the hot pinhole ignites the gas and then we have a fire…like a blow torch wherever it is," says a Mount Pleasant Battalion Chief.

A home on Johns Island was struck by lightning about a month ago and officials have determined the same problem. More than 40,000 homes in the tri-county were built between 2003 and 2007, a time when the piping was widely used.

Two years ago installation procedures changed after the lightning danger was unveiled. It's now state law that the gas line be grounded.

Homeowners are urged to call a certified gas installer to check their piping. It's a proactive approach officials say that could keep your house standing should it be singled out.

Mitch Guthrie indicated that the only evidence of a direct strike was from the news report but the report also quoted Mt. Pleasant fire inspectors saying they believe the lightning traveled into the home on CSST the gas line. There appeared to be no damage to the CSST runs in the attic or anywhere else in the house, except the one in the crawl space running to the fireplace. The structure was provided with a municipal gas supply.

Grounding was present on the service entry at the meter. The measured soil resistivity was found to be 6.6 ohm-m, the measured resistance to earth of the incoming gas line was 1.8 ohms (both very good) and the bonding resistance between the electrical service ground and gas service entry was 0.82 ohms. The gas service entered the structure on one side while all other services entered on the other side. The fire occurred in a section of CSST located in the crawl space in the vicinity of the gas fire place approximately 12 feet from the bonding point at the service entry.

Gas Meter Bond

A3.8 Place of event: Lafayette, Indiana / Date of event: June 25, 2006

Name of file:	Pilotte Fire Report.pdf
Title:	Division of Fire Safety Fire Investigations REPORT OF FIRE INVESTIGATION
Author:	Frederick J. Sumpter, IAAI-CFI
Date of publication:	September 18, 2006
Place of event:	Lafayette, Indiana
Date of event:	June 25, 2006
Direct strike?	Yes
CSST bonded?	?
Electrical lines involved?	?
Comment	LP storage tank. This event in Indiana led to specific training to Indiana fire departments regarding CSST. Thus, they may be more aware of the possibility of CSST-related incidents than fire departments in other states.

Detailed investigation:

Construction was ranch style, site built, on a partial basement. The exterior was finished with horizontal double-four vinyl siding. The roof was asphalt-based shingles. The sub-floors were wood or poured concrete, bare. The walls in the area of origin were bare poured concrete and unfinished drywall. The ceiling was open manufactured wooden I-beams for the first floor. The sub-floor was bare poured concrete.

Information was received that the female neighbor stated that there was a lightning storm in the area at the time. During the storm she observed a large bolt of lightning strike close to the house with a loud sound of thunder.

Being scared about the storm and her mobile home, the neighbor began walking front to back inside of her residence. At one point she looked out of her east windows and observed a white or light gray smoke coming from the residence where the event occurred. The neighbor described the light colored smoke as venting the structure.

A small area of charring was located along the east bottom portion of the door jamb for the north entrance. Charring in this area was identified as resulting from the flames openly burning inside the basement of the structure.

A central air-conditioning unit was located along the west side of the structure. Examination of the appliance revealed no damage along the exterior resulting from the event. No attempts were made to examine the overcurrent protection device due to the lack of damage along the exterior of the branch service panel.

Two electric service panels were located east of the electric meter base. One of the panels was identified as the main disconnect for the service, and the second was thought to be a main disconnect for the outbuildings south of the residence. Examination of the exterior of the panels revealed no evidence of damage resulting from the event.

Breakers were identified inside both panels. The breaker in the west panel, closest to the meter base, appeared to be in the “off” position. The breaker in the east panel was identified in the “tripped” position. No determination could be made at the time indicating how the breakers were placed in their positions.

An LP storage tank for the residence was located in the yard several feet south of the structure. Examination of the tank revealed no damage resulting from the event. The valves, main fuel gas line, fuel capacity gauge, and first stage regulator were all found in place at the time of the examination. No evidence of an internal failure was identified that could have resulted in leaking fuel adding additional damage to the structure.

The second-stage regulator was located along the south wall of the residence, just west of the electrical service entrance. Examination of this item revealed no damage resulting from the event. No evidence of an internal failure was noted in the regulator or the fittings connecting the regulator to the main fuel gas line from the storage tank or the main line entering the structure.

A large hole was found in the floor of the foyer for the north main entrance of the residence.

A small LG gas space heater was located near the center of the east wall of the east basement room. Examination of the appliance revealed damage resulting from radiant heat, fire gases, and falling burning debris during the event. No evidence of an internal failure was identified in the main fuel gas line extending from the southwest corner of the furnace to the appliance or the fuel gas line entering the fuel gas control valve.

An electric water heater was located in the southwest corner of the west basement room. Damage to the appliance was identified as resulting from radiant heat and fire gases. The fire gases had stained the exterior of the appliance during the event.

Examination of the electrical conductors providing service to the appliance revealed damage resulting from radiant heat and fire gases. No evidence of an internal failure or areas of resistive heating was identified in these conductors or the internal conductors for the appliance prior to the ignition of the flames.

The main fuel gas lines to the appliance were identified by Investigator Jim Wood of the Tippecanoe County Fire Investigation Team as corrugated stainless steel tubing (CSST). This type of fuel gas line has been recently noted as failing during certain conditions, including lightning storms, resulting in the ignition of fires.

An uninstalled roll of Pro-Tech CSST fuel gas line was located along the south wall of the west basement room. The roll was photographed in place and the name was noted for this report. A manifold, a divider of the fuel gas line entering the structure, was located near the ceiling for the west basement room along the south wall. Examination of the manifold revealed no evidence of internal failure. Damage to the exterior of the item was identified as resulting from radiant heat and fire gases.

Fuel gas line extending away from the manifold was identified as terminating at the LP gas furnace in the east basement room and the pool heater near the southeast corner of the east basement room. No evidence of damage, other than radiant heat and fire gases, was identified to the line terminating at the pool heater.

The fuel gas line that separated the heat runs west of the furnace, which was identified with the yellow protective coating, was compromised by direct flame impingement. No attempts were made to manipulate the fuel gas lines, in an attempt to protect the physical evidence for later insurance investigators. The movement or manipulation of the lines could have become a spoliation or destructive testing issue.

Evidence of a possible lightning strike was identified on the mast to the TV antenna located on the roof of the structure near the southeast corner. The coaxial type cable that had been taped to the metal mast was identified as being compromised. Striations on the mast were identified as resulting from a current passing through the metal, along the coax, during the passing storm.

At the time of this examination, the fire was determined to be natural. The area of origin was identified as the ceiling above the west basement room, west of the LP furnace. The possibility of a lightning strike from a thunderstorm moving through the area, resulting in the CSST being compromised, could not be ruled out as the ignition source for this event.

During the second scene examination with the private sector investigators and another signed consent to search, a more detailed examination of the scene was completed. The fuel gas lines were tested during this return visit to the scene. During the scene examination, it was determined that there were two types of CSST installed in the residence. The fuel gas line, CSST, leading to the LP furnace and then bifurcating to the LP space heater was of one brand. The type leading to the pool heater was of another brand.

The fuel gas line entering the residence was tested and found to be intact. No evidence was identified by the investigators indicating an internal failure in the line prior to the event.

The fuel gas line providing service the pool heater was identified as ½" CSST. No internal failures were identified inside the fuel gas line, and it held a pressure of 12" water column. The fuel gas line to the furnace was identified as 3/8", and it held a pressure of 12.5" to 13.0" water column. These tests indicated that the CSST had not failed prior to or during the event.

An examination of the antenna mast revealed the top portion of the coax had been compromised at the connection. The area where the striations were was measured 55" above the roof, with the coax again being compromised. An additional charred area on the roof was located 99" northwest of the mast. This evidence indicated that a possible lightning strike to the residence may have occurred. Based on these facts, this fire was determined to be natural. The area of origin was identified as the west side of the LP furnace in the east basement room. The possibility of a lightning strike could not be ruled out as the ignition source for this event. No evidence was identified indicating that the CSST had failed, allowing additional free flowing fuel gases into the basement and increasing the burn rate of the available material, prior to the arrival of the suppression crews.

Note that in the above mentioned case there was unfortunately an Indiana firefighter death, which led to specific training on CSST in Indiana.

A3.9 Place of event: Florida / Date of event: May 13, 2007

Name of file:	LPS CSST Incident May 2007.docx
Title:	CSST Lightning Incident
Author:	Private communication
Date of publication:	October 6, 2010
Place of event:	Florida
Date of event:	May 13, 2007
Direct strike?	No
CSST bonded?	Yes
Electrical lines involved?	No
Comment	CSST damage was close to the bonding conductor where it was running parallel with the CSST. Apparently flashover occurred between two CSST runs.

Detailed investigation:

Lightning is believed to have struck the neighbors' flag pole. The homeowner was in his garage and heard what he described as the sound of an operating furnace. Upon further investigation, he determined that it was coming from overhead and ascended the attic stairs to investigate. He found a 6 ft flame burning on the CSST gas line.

He called his neighbor, who shut off the gas before the fire could spread and saved the home. In the photograph, note the # 6 copper ground wire adjacent to the site of the CSST burned area. Bonding of CSST is made at manifold using this#6 AWG bonding conductor.

The home did not lose power, nor was there any surge damage to appliances/electronics even though at the time there was no surge protection. Following the incident the home owner found that the telephone line had not been properly grounded.

The gas piping was repaired by a plumbing contractor using 20 ft of 1/2" CSST and two splices.

A3.10 Place of event: Indiana / Date of event: July 8, 2008

Name of file:	Private communication
Title:	None
Author:	Private communication
Date of publication:	None
Place of event:	Indiana
Date of event:	July 8, 2008
Direct strike?	No
CSST bonded?	Yes
Electrical lines involved?	Telecom line
Comment	Bonding was not made according to code. It is likely that surge current came from the telecom line and then flowed through the CSST due to common bonding. Voltage drop along the CSST and bonding wire creates a high voltage at the CSST, and sparkover occurs where distance is minimal to a metal part or electrical conductor

Detailed investigation:

Lightning damaged telecom equipment. The telecom equipment was bonded to the CSST manifold in violation of Indiana gas code.

A hole occurred at the CSST very close to HVAC metal duct and wiring. The CSST was bonded with a #4 AWG at the first manifold to the water supply.

A possible solution is global bonding or a shorter bonding conductor, if possible.

A3.11 Place of event: South Carolina / Date of event: August 13, 2010

Name of file:	Private communication
Title:	None
Author:	Private communication
Date of publication:	None
Place of event:	South Carolina
Date of event:	August 13, 2010
Direct strike?	Yes
CSST bonded?	Yes
Electrical lines involved?	?
Comment	Bonding was not fully compliant with code (two different ground rods were present).

Detailed investigation:

Direct lightning to the building creating a fire in the attic. CSST there was bonded with a#6 AWG to a specific grounding rod different from (and not connected to) the electrical ground rod.

No damage to CSST was reported, except burning of the jacket of the CSST connected to furnace.

A3.12 Place of event: Indiana / Date of event: March 12, 2010

Name of file:	Private communication
Title:	None
Author:	Private communication
Date of publication:	None
Place of event:	Indiana
Date of event:	March 12, 2010
Direct strike?	Apparently
CSST bonded?	Yes
Electrical lines involved?	Yes
Comment	This incident could have been caused by a direct strike to the roof with current flowing through electrical wiring and jumping to CSST.

Detailed investigation:

There was a short distance between the CSST and wiring in the attic. Electrical circuitry was damaged. A hole occurred in the CSST very close to electrical wiring.

The CSST was bonded with a #4 AWG at the entrance to the water supply.

A3.13 Place of event: Ohio / Date of even : June 1, 2009

Name of file:	Private communication
Title:	None
Author:	Private communication
Date of publication:	None
Place of event:	Ohio
Date of event:	June 1, 2009
Direct strike?	No
CSST bonded?	No
Electrical lines involved?	?
Comment	Damage was due to lightning coming from a gas pipe with no bonding.

Detailed investigation:

Lightning entered through the black gas pipe, leaving arcing marks on a tracer wire. A hole occurred in the CSST. Possible arcing marks were left on a metallic vent.

The CSST was not bonded.

This Fire started in basement ceiling area.

A3.14 Place of event: Oklahoma / Date of event: May 31, 2010

Name of file:	Private communication
Title:	None
Author:	Private communication
Date of publication:	None
Place of event:	Oklahoma
Date of event:	May 31, 2010
Direct strike?	Yes
CSST bonded?	Yes
Electrical lines involved?	?
Comment	There was no metallic part or conductor near the hole.

Detailed investigation:

No electrical wiring or metal part was adjacent to CSST. A hole occurred in the CSST close to a wood framing member. The CSST was bonded to the circuit breaker panel (the electrical system was grounded by a rod).

The fire started over the garage due to a direct strike on the roof (damaged bricks can be seen).

A3.15 Place of event: Pennsylvania / Date of event: May 7, 2009

Name of file:	Private communication
Title:	None
Author:	Private communication
Date of publication:	None
Place of event:	Pennsylvania
Date of event:	May 7, 2009
Direct strike?	Yes
CSST bonded?	Yes
Electrical lines involved?	?
Comment	No damage to CSST in spite of direct lightning to the house.

Detailed investigation:

There was no CSST damage.

No CSST was near where fire started.

The CSST was bonded to the electrical panel at the manifold.

A3.16 Place of event: Florida / Date of event: July, 2005

Name of file:	LPS CSST GAS PIPE LIGHTNING EXPERIENCE.doc + private communication
Title:	CSST GAS PIPE LIGHTNING EXPERIENCE
Author:	Private communication
Date of publication:	October 6, 2010
Place of event:	Florida
Date of event:	July, 2005
Direct strike?	No
CSST bonded?	Yes, according to oral report
Electrical lines involved?	No
Comment	CSST with flame during thunderstorm.

Detailed investigation:

Direct Lightning Experience Since 2004: Seven homes have been destroyed by direct lightning strikes in the last six lighting seasons. All seven homes were supplied with natural gas and presumably had CSST. Four incidents occurred before the CSST issue became public, and three have occurred since. In no case did the official investigation report state that CSST was a contributing factor. Eyewitness reports indicate that in five cases, the initial fire seemed to be most intense above the garage – the location of the CSST gas manifold. In one case, the NFIRS report indicated that firefighters were not able to shut off the gas below the external meter due to the intensity of the garage fire above their heads. In another case, the homeowners evacuated the house after a lightning strike and heard an explosion in the attic garage area. When the house was rebuilt, gas was capped at the street and the homeowners went all electric, as did their next door neighbor.

None of the homes described above were protected by a lightning protection system.

There have been five reports of CSST gas line fires that were discovered by the homeowner. In four of the five events, the fire department was called and the home was saved. In the fifth, the fire was believed to have self-extinguished. Four were from indirect lightning strikes, and one was a direct lightning strike. Two occurred before there was knowledge of the CSST class action lawsuit, and three have occurred since that issue became public. In one of the cases, the homeowner found an 18 inch flame burning in garage attic on CSST gas line during a thunderstorm.

A3.17 Place of event: Lima, Ohio / Date of event: May 17, 2006

Name of file:	05172006.PDF
Title:	NFIRS form
Author:	State of Ohio Fire Marshal
Date of publication:	May 17, 2006
Place of event:	Lima, Ohio
Date of event:	May 17, 2006
Direct strike?	?
CSST bonded?	?
Electrical lines involved?	Yes
Comment	No details

Detailed investigation:

This NFIRS form is in all caps :

ARRIVED TO FIND NUMEROUS OUTLETS BLOWN OUT OF BOXES, MAIN BREAKER IN PANEL TRIPPED,WALL AND CEILING PLASTER BLOWN OFF IN NORTH BEDROOOM ON SECOND FLOOR, AND SMALL FIRE IN BASEMENT. BASEMENT FIRE WAS THE RESULT OF AN APPARENT LIGHTNING STRIKE THAT CAUSED WIRING TO ARC AT A SPLICE, WHICH BURNED THROUGH A FLEXIBLE NATURAL GAS LINE, IGNITING THE GAS. GAS WAS SHUT OFF, EXTINGUISHING FIRE WITH NO SPREAD. SIGNIFICANT AMOUNT OF OVERHAUL DUE TO ELECTRICAL SYSTEM DAMAGE. AEP CALLED FOR DISCONNECT. WATER SHUT OFF DUE TO LINES MELTED BY FIRE. RED CROSS CALLED FOR HOUSING ASSISTANCE.

A3.18 Place of even : Lewis Center, Ohio / Date of event: May 21, 2004

Name of file:	05212004.PDF
Title:	NFIRS form
Author:	State of Ohio Fire Marshal
Date of publication:	May 21, 2004
Place of event:	Lewis Center, Ohio
Date of event:	May 21, 2004
Direct strike?	?
CSST bonded?	?
Electrical lines involved?	?
Comment	No details

Detailed investigation:

This NFIRS form is in all caps :

RESPONDED TO REPORTED STRUCTURE FIRE. MAIN AREA OF ORIGIN WAS THE BASEMENT AREA, AND EXTENDED THROUGH THE FIRST FLOOR. TWO CATS WERE LOST IN THIS FIRE, WITH NO OTHER INJURIES REPORTED. THE CAUSE OF THE FIRE WAS A LIGHTNING STRIKE THAT CAUSED GROUNDING OF THE COORUGATED STAINLESS STEEL TUBING (CSST) LOW PRESSURE GAS LINE, WHICH BLEW A PINHOLE AND IGNITED THE GAS, CAUSING BURNING OF THE FLOOR STRUCTUE.

A3.19 Place of event: Delaware, Ohio / Date of even :June 19, 2009

Name of file:	06192009.PDF
Title:	NFIRS form
Author:	State of Ohio Fire Marshal
Date of publication:	June 19, 2009
Place of event:	Delaware, Ohio
Date of event:	June 19, 2009
Direct strike?	?
CSST bonded?	?
Electrical lines involved?	Yes
Comment	No details

Detailed investigation:

This NFIRS form is in all caps :

HOUSE STRUCK BY LIGHTNING, 4 CIRCUIT BREAKERS POPPED, NOTHING SHOWING, OUT INVESTIGATING, FIRE IN A CRAWL SPACE.

The general description of this property is 1 or 2 family dwelling.

The involved structure is described as an enclosed building. The building was occupied and operating. Attic: vacant, crawl space above top story best describes the primary use of the room or space where the fire originated.

This building has two stories above ground. The fire occurred on the first floor below grade. The fire was confined to the room of origin. Lightning best describes the heat source that caused the ignition. An act of nature caused the ignition. The building was equipped with smoke detectors. The detection system was hardwired with battery backup. The detector(s) operated properly. The detector(s) alerted the occupants and the occupants responded. The estimated property loss on this incident was $5,000. The estimated property value was $183,000. The estimated content value was $91,500

Investigation throughout the house identified that the source of the smoke was located in the basement crawlspace on side B.

Gas was shut-off at the exterior gas main side B. No other problems found throughout the building. Fire appears to have been caused by a lightning strike. Fire was contained to the crawl space area. The occupant did find an outlet to the right of the kitch sink that was also damaged. The fire appears to have involved the CSST piping for the gas service inside the residence.

A3.20 Place of event: Dublin, OH / Date of event: July 22, 2004

Name of file:	07222004.PDF
Title:	NFIRS form
Author:	State of Ohio Fire Marshal
Date of publication:	July 22, 2004
Place of event:	Dublin, OH
Date of event:	July 22, 2004
Direct strike?	Yes
CSST bonded?	?
Electrical lines involved?	?
Comment	Hole on the CSST close to steel beam.

Detailed investigation:

Fire Department was advised by dispatch that homeowner at noted address called and stated he thought his house was struck by lightning, and that his wife woke and smelled smoke. When [homeowner] checked the basement he found a moderate amount of smoke. As he went further into the basement he saw flames coming from a plastic wrapped flexible gas line that runs under the first floor. He immediately shut off gas line and fire was extinguished.

The gas line that ruptured fed a gas log fire place, where it ruptured and caught fire ran directly beneath a large steel I beam support. The flames spread upward and charred the 2 x 8 floor joist directly above it. Charring was minimal. Heat from fire also created a small pinhole leak in a pvc water line running just below gas line. Shut off water valve to that line.

Steel beam was slightly over 200 degrees per thermal camera upon our arrival. Was reading at just over 100 degrees when unit left the scene. Homeowner’s security system and phones were also knocked out. No electrical breakers were popped in main electrical panel. Crew found no visible entry points where lightning strike hit. Possibly struck the chimney cap, ran down the metal chimney liner to the gas line.

A3.21 Place of event: Zanesville, OH / Date of event: July 27, 2007

Name of file:	07272007.PDF
Title:	NFIRS form
Author:	State of Ohio Fire Marshal
Date of publication:	July 27, 2007
Place of event:	Zanesville, OH
Date of event:	July 27, 2007
Direct strike?	?
CSST bonded?	?
Electrical lines involved?	Yes
Comment	No details

Detailed investigation:

This NFIRS form is in all caps :

DISPATCHED TO HOUSE FILLING WITH SMOKE AFTER LIGHTNING STRIKE. ON ARRIVAL FOUND SMOKE COMING FROM CHIMNEY AND OTHER AREAS. OCCUPANTS WERE ALREADY OUT. ON ENTRY FOUND BASEMENT FILLED WITH SMOKE AND NO VISIBILITY. PUT ATTACK LINE IN PLACE AND VENTED BASEMENT WINDOWS. FOUND FIRE CONFINED TO SPACE BETWEEN TWO FLOOR JOISTS IN BASEMENT CEILING. SHUT OFF GAS WHEN GAS SMELL WAS DETECTED. ON OVERHAUL FOUND SOME KNOB AND TUBE TYPE WIRING WHICH HAD POSSIBLY SHORTED OUT ON DUCT WORK. FOUND TWO CIRCUIT BREAKERS TRIPPED. ALSO FOUND SMALL PINHOLE BURNT IN FLEXIBLE GAS LINE USED TO SUPPLY GAS FIREPLACE. THIS WAS RIGHT WHERE THE FIRE DAMAGE WAS GREATEST. MOVED OCCUPANTS' BELONGINGS OUT OF AREA AND REMOVED SOME DUCT WORK TO GAIN BETTER ACCESS FOR OVERHAUL.

A3.22 Place of event: Florida / Date of event: September, 2005

Name of file:	LPS CSST GAS PIPE LIGHTNING EXPERIENCE.doc + private communication
Title:	CSST GAS PIPE LIGHTNING EXPERIENCE
Author:	Private communication
Date of publication:	October 6, 2010
Place of event:	Florida
Date of event:	September, 2005
Direct strike?	No
CSST bonded?	Yes, according to oral report
Electrical lines involved?	Yes
Comment	Damage to CSST initially unnoticed. Only gas leak.

Detailed investigation:

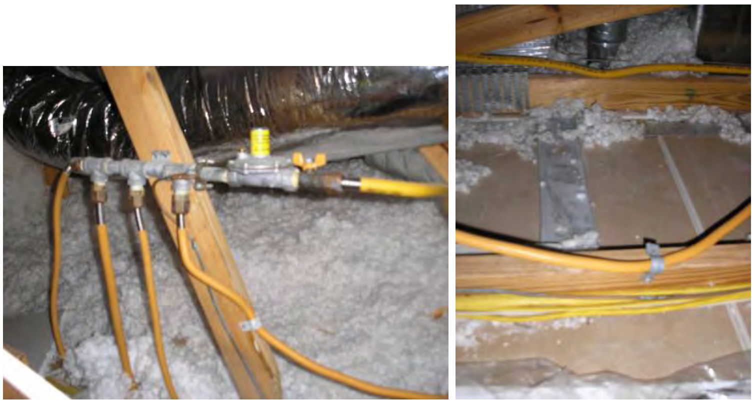
The homeowner had experienced unusually high gas bills and the meter had been changed out by the gas utility. Later, the homeowner experienced the strong smell of gas when he opened his bathroom medicine cabinet. He called the gas utility and a plumber who found a charred 2 x 6 joist in the garage attic and a hole in the CSST gas pipe. Apparently, the fire self-extinguished. The homeowner recalls strong lightning in the area 2-3 weeks before this discovery; At that time, he experienced damage to a stereo system.

A3.23 Place of event: Florida / Date of event: May 13, 2007

Name of file:	LPS CSST GAS PIPE LIGHTNING EXPERIENCE.doc + private communication
	CSST GAS PIPE LIGHTNING EXPERIENCE
Author:	Private communication + Mitch Guthrie
Date of publication:	October 6, 2010
Place of event:	Florida
Date of event:	May 13, 2007
Direct strike?	No
CSST bonded?	Yes
Electrical lines involved?	Yes (loss of power)
Comment	Measurement of a high frequency of grounding impedance at both the ground rod and gas supply entrance show that they are consistent (bonded together) but the gas supply behaves slightly better than the ground rod.

Detailed investigation:

The NFIRS report indicates that there was a gas leak from a gas line in the attic and flame showing from the leak. The fire was extinguished by turning off gas.



Bonding Only at Manifold (left), and Location of Incident (right)

Mitch Guthrie indicated the following (from a private copy of one of his yet unpublished reports):

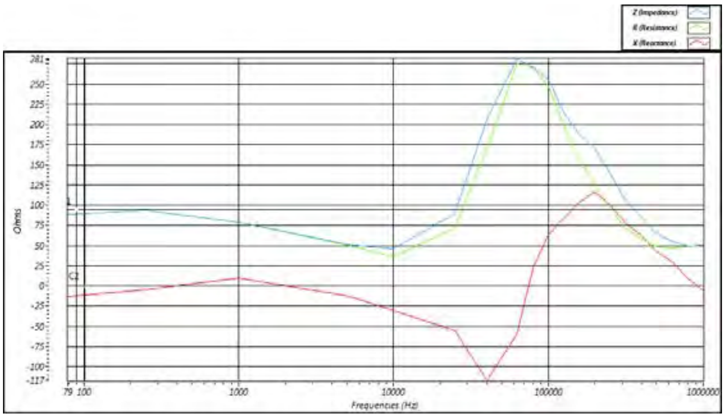
"In the second case investigated at the Villages, the homeowner experienced loss of power during a thunderstorm. He went into the garage to investigate and heard a “fluttering” sound coming from the garage attic. An investigation revealed a 6-inch flame burning on a CSST gas line. It was suspected that sometime during the storm an arc occurred between a CSST and an isolated metallic component used to support in the installation of sheetrock making up the ceiling of the garage. There was no evidence of a direct strike in this instance and the homeowner was home at the time of the event. The damage had been repaired at the time of the site visit but, based on information provided by the homeowner, the event occurred on a section of CSST coming from the riser to supply the manifold at the metal strut running between the rafters shown in Figure above. The CSST piping shown in the bottom of the picture was routed between the rafters, laying on the metal strut at the time of the incident. A detailed review of the routing of the CSST revealed numerous cases where the CSST was in close proximity to and in some cases making contact with metal but there was no damage at these locations."

The service entrance configuration for this case was similar as for other cases. There was no evidence of external bonding between the gas line and power service ground rod, but there was a bare copper wire running between the ground rod and the manifold in the attic above the garage, as shown in the figure above.

Grounding system impedance measurements were made from the incoming gas line (see the figure below) and from the ground rod for the power service which is used as the ground reference point for the manifold.

Impedance Test Point for Incoming Gas Line

The graph below shows the grounding system impedance versus frequency for the incoming gas line.



Impedance versus Frequency for Gas Line at Service Entry Point for the second case investigated at the Villages

The low frequency value is found to be approximately 89 ohms. The average high frequency impedance of the gas line at the service entrance was found to be 148.8 ohms; a significant capacitive effect at frequencies above 100 kHz which dropped the impedance at 1MHz to 49.6 ohms.

The impedance versus frequency graph for the grounding electrode measured at the test point shown in the figure below was seen to exhibit characteristics of what would be expected for a driven rod at low frequencies starting at 102 ohms and dropping to 52.8 ohms at 5 kHz. Average high frequency impedance is 111 ohms.

Grounding Electrode for Electrical Service and Manifold Ground Reference

A3.24 Place of event: Florida / Date of event: August, 2008

Name of file:	LPS CSST GAS PIPE LIGHTNING EXPERIENCE.doc + private communication
Title:	CSST GAS PIPE LIGHTNING EXPERIENCE
Author:	Private communication
Date of publication:	October 6, 2010
Place of event:	Florida
Date of event:	August, 2008
Direct strike?	No
CSST bonded?	Yes, according to oral report
Electrical lines involved?	?
Comment	No details

Detailed investigation:

During a thunderstorm, the homeowner heard very loud and close thunder. He went outside and found no evidence of a direct lightning strike. When he went back inside, he smelled smoke. He entered the garage attic through a hatch and found flames burning on a 2 x 6 joist above the hot water heater. At that time, he did not realize that the fire involved both the wood joist and natural gas. He used a portable hand fire extinguisher to put out the fire. A week later, a contractor working in the attic smelled gas and upon investigation found that the CSST line adjacent to the HWH vent was charred and breached.

A3.25 Place of even : Florida / Date of event: August 22, 2009

Name of file:	LPS CSST GAS PIPE LIGHTNING EXPERIENCE.doc
Title:	CSST GAS PIPE LIGHTNING EXPERIENCE
Author:	Private communication + Mitch Guthrie
Date of publication:	October 6, 2010
Place of event:	Florida
Date of event:	August 22 2009
Direct strike?	Yes
CSST bonded?	No visible bond
Electrical lines involved?	?
Comment	Fire was created by a CSST leak. Location of the CSST leak was clearly identified. Bonding with high impedance was present between CSST and the ground rod.

Detailed investigation:

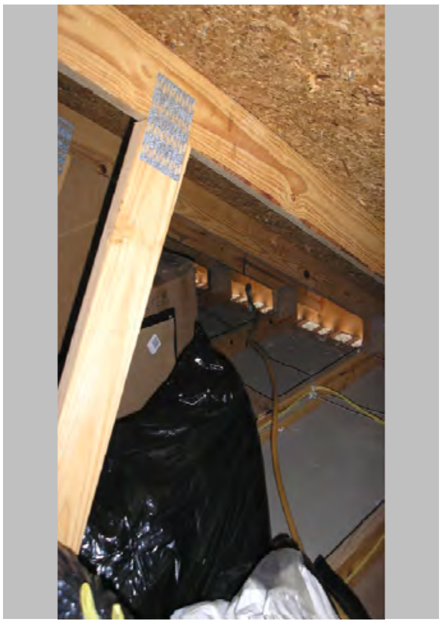
Lightning struck the roof but did not start a fire. However, the CSST gas line was breached, and fire was knocked down by the homeowner using a hand portable fire extinguisher.

The NFIRS report indicates that a small 3" x 3" burned area was found with gas line plastic melted.

Place of Sparkover Between Metal Vent and CSST. (Note that CSST is now at distance from the initial position.)

Mitch Guthrie indicated the following (from a private copy of one of his yet unpublished report):

Electrical testing was performed on 3 September, 2010. For Case 1, identified as receiving a direct strike, it is unclear as to whether there was an eyewitness to the event but the homeowner was home at the time and indicated he heard experienced very loud and close thunder. The NFIRS report for the incident indicated that firefighters responding to a resulting fire call found a hole in the ridge vent of approximately 2 inches by 2 inches. No StrikeFax was obtained for this incident. The result of the event was small fires in the attic above the garage and in the master bathroom ceiling. In both these areas, NFIRS indicated the fire resulted in a 3-inch by 3-inch burned area with indication of the presence of a gas line with plastic coating melted in the location above the garage. No such indication was noted for the fire in the master bathroom ceiling. A week after the event a contractor working in the attic smelled gas and upon investigation found that the CSST line adjacent to the hot water heater vent was damaged. The figure above forwards a picture of the burned area and electrically-isolated hot water heater vent showing the repaired CSST piping. The damaged section of piping was removed, spliced as shown, and supported above the hot water heater vent. The incoming gas service is municipal and metered, enters the structure at the meter and rises to the attic area using galvanized piping. The transition to CSST is made at the entry point to the attic. The CSST coursing from the transition point to the manifold runs across and in close proximity to electrical wiring in the attic. The figure below shows the installation of the manifold and the solid #6 AWG copper wire used to ground the manifold through the electrical service ground rod. This appeared to be a common practice here, or at least it was a consistent technique found at the locations visited as a part of this survey. As you can see from this series of photos, the failure point in the CSST piping in Case 1 was in the section of CSST on the source side of the manifold and prior to the grounding of the CSST.



Routing of Incoming CSST Piping

Manifold Installation with Grounding

High frequency grounding impedance measurements were made on the electrical service entrance grounding electrode and on the customer side of the gas meter. The grounding electrode test point shown in the figure below was found to be a good lightning protection ground given the criteria used by the test equipment used to make the measurement. The grounding electrode exhibited an average high frequency impedance of 38.3 ohms. The test results for the gas entry point at the customer side of the meter indicate an average high frequency impedance of the gas line at the service entrance was found105.8 ohms; much higher than the grounding electrode average of 38.3 ohms.

Grounding Electrode Test Point Configuration

Gas Service Entry Point

The figure below shows the relative location between the service entrances for the phone, electrical power, and gas. There was no visual evidence of an external bond between the gas service entry point and the electrical service ground.

Service Entry Locations for Electric, Gas, Phone, and Cable

One of the figures above shows the manifold ground wire tied to the grounding electrode. If one were to assume that the incoming gas utilizes plastic piping, it is reasonable to assume that the most significant portion of the 47.2 ohm difference in the low frequency impedance can be attributed to the CSST gas line running between the manifold and the incoming gas line riser. At higher frequencies, the sharp bend in the grounding conductor will also be a contributor to the overall impedance.

A3.26 Place of event: Fairview, North Carolina / Date of event: < June 20, 2008

Name of file:	Private communication
Title:	Private communication
Author:	Mitch Guthrie
Date of publication:	
Place of event:	Fairview, NC
Date of event:	< June 20, 2008
Direct strike?	No
CSST bonded?	Yes
Electrical lines involved?	Yes
Comment	Buried tank. CSST created a flame for some days. No metal part or conductor was in close vicinity.

Detailed investigation:

The site is supplied by a buried tank and is located on top of a mountain. The soil is made of rock with very high soil resistivity.

The fire was discovered on June 20, 2008, having arrived the night before to no water, the two electric lines that burned through above the track pipe fed the well pump and the water heater. The fire had been burning for some time before the owner came back home. The CSST damage location was near a plastic water pipe. Electrical cables as well as a metal pipe are running above the CSST at some distance.

It is not clear if the bonding at entrance of gas installation was present before the event, but in any case the bonding at the manifold was present before the event. The electric line entrance and gas entrance are located next to each other.

A radio tower is located nearby on top of the hill and is the nearest neighbor. This tower could have been the location of the lightning strike, but some people also mentioned a tree being damaged by lightning in the vicinity around the same time.

View of the Damaged CSST Near Two Vertical Plastic Pipes and Above CSST Electrical Cables, as well as a Metallic Pipe Run Horizontally

Electric and Gas Supply

A3.27 Place of event: New Bern, NC / Date of event: July, 2009

Name of file:	Private communication
Title:	Private communication
Author:	Mitch Guthrie
Date of publication:	
Place of event:	New Bern, NC
Date of event:	July, 2009
Direct strike?	No
CSST bonded?	Yes, to LPS
Electrical lines involved?	?
Comment	Buried tank. Multiple holes (2) with no metal part in vicinity.

Detailed investigation:

The structure investigated in this case was a 1.5 story, pitched roof, single-family dwelling equipped with a lightning protection system installed in June 2006; the LPS received a UL Master Label on July 19, 2006. Grounding for the LPS consisted of 4 3/4-inch by 10-foot long driven copper rods, one on each corner. The ground rods were interconnected through the down conductors and roof conductors. Surge protection was not provided as part of the Master Label, but there was some surge protection provided on both the incoming power and telephone.

The structure is located in a suburban location near a river, near homes of generally the same height and numerous pine trees. The dimensions of the structure are approximately 79 feet wide by 53 feet deep with a peak height of 35 feet in the center, and all services provided to the structure enter underground. Services provided include water, gas, electric, telephone, and cable TV. The electrical service, telephone, and cable TV all entered the structure near the southeast corner of the structure. Water appeared to enter the structure on the north side of the northwest corner.

Gas service for the structure consists of a 350-gallon metallic tank buried between the residence and the street and is fed to the structure through buried copper pipe. It enters the structure through three regulators and transitions to CSST where it passes through a cinder block wall into the crawl space. The incoming line is bonded to the nearest LPS grounding electrode at the entry point on the supply side, just below the regulators.

Gas utilization in the structure consisted of a furnace on the first floor near the service entry, a cook top in the same general area, a gas fireplace along the south wall, a gas grill on the deck on the south side of the structure, and two tankless water heaters (a smaller one near the entry point and a larger one in the garage area on the east side of the structure).

Neighbors said that they saw a lightning strike in vicinity of the house. The homeowner was not present at the time of the incident but returned a few days later. He first became aware of the problem when he attempted to wash his hands and noticed the cold water was excessively hot. He went to the crawl space and noticed a flame coming from a CSST pipe just after the point it enters the crawl space and bends upward.

The soil resistivity was measured and found to be a good one: 41 ohm-meters.

After the event (approximately one month before the site visit), an additional ground rod had been added to the LPS on each of the corners on the north side. The original ground rod to which the CSST was bonded had a resistance value (when visited some months after the event) of 22.6 ohms. When all rods are connected together, the earth resistance value goes down to 1.45 ohms. It is interesting to note that all services enter from one side of the house except the gas, which comes in from the opposite side of the house.

Damage can be seen on the CSST near a concrete block wall (no re-bar). The nearest metallic part is a copper water pipe located around 4 feet from the CSST holes (there are two holes on the CSST at the same location).

Location of CSST Hole Near the Wall

A3.28 Place of event: John Island, SC / Date of event: July or August, 2009

Name of file:	Private communication
Title:	Private communication
Author:	Mitch Guthrie
Date of publication:	
Place of event:	John Island, SC
Date of event:	July or August, 2009
Direct strike?	No
CSST bonded?	?
Electrical lines involved?	?
Comment	Damage to two brands of CSST within a month at the same location, including a CSST specifically designed for enhanced lighting withstand.

Detailed investigation:

The single-family residence sits near the coast of Johns Island, SC on pilings. The peak of the structure rises approximately 40 to 45 feet above local earth. The pilings are equipped with straps that secure the structure to the pilings. Local earth was generally found to be sandy, and earth resistivity measurement resulted in a recorded value of 519,000 ohm.m. In spite of this bad soil resistivity, a structural strap on a piling for the house was tested and found to have a good resistance to earth value, 24.5 ohms compared to the ground rod at the electrical service entrance when isolated from the structure (3,970 ohms). The gas pipe connected to the buried tank was measured and found to have a resistance to ground of 23.6 ohms, showing that it is connected to house footings one way or another.

Electrical service enters the structure underground from a transformer located near the entrance of the driveway (approximately 40 to 50 feet away). Incoming gas service is provided by a 300 to 350 gallon metallic tank buried approximately 20 to 25 feet from the structure. All other services enter on the other side of the structure. The homeowner indicated that he thought the incoming gas line was bonded prior to the first event, but the gas service provider did not agree. As a part of the repair from the first event, the gas service provider installed the bond to the electrical service ground. No surge protection could be identified on the incoming services.

The gas service entered the structure using buried “black pipe” from the tank to a piling of the structure. CSST ran up the piling to the floor joists, across to the top of an adjacent piling where it made a 90-degree bend, then ran toward the center of the structure where it teed off to other runs throughout the structure. The only line in use was for a water heater.

The structure experienced two lightning-related CSST incidents within a one month period. The homeowner also offered that a local fire department worker at the site related to him that there were 34 CSST-related problems in the greater Charleston area that year.

The damaged section of original CSST installed at this site was replaced with a CSST specifically developed for enhanced lightning withstand characteristics, but one month later another damage occurred exactly at the same location. It was found that the installation technique at this site was likely a major contributor to these events because the piping was routed along the top of the pilings within a few inches of the well-grounded straps in the pilings.

Neither event appeared to involve a direct strike to the structure. In the initial event, the structure lost power and the transformer providing power to the structure had to be replaced. In the second incident, there was no other damage reported, other than the breach of the CSST and resulting fire.

Location of the CSST Damage Near a Strap Connected through a Concrete Column to the House Basement

Gas Bonding

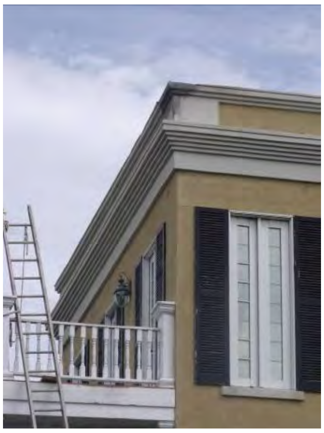
General View of the House Showing the Lack of Lightning Electromagnetic Shielding Provided by the Structure

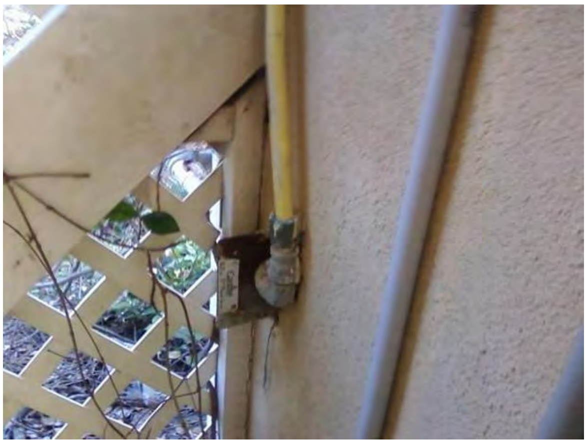
A3.29 Place of event: Folly Beach, SC / Date of event: ?

Name of file:	Private communication
Title:	Private communication
Author:	Mitch Guthrie
Date of publication:	
Place of event:	Folly Beach, SC
Date of event:	?
Direct strike?	Yes
CSST bonded?	No
Electrical lines involved?	Yes
Comment	Direct strike. No bond. No CSST problem.

Detailed investigation:

Eyewitnesses reported a direct strike to a 4-story residence located on the edge of a salt marsh. Municipal gas service was provided which transitioned to CSST throughout the structure. There was physical evidence of a direct strike to a corner of the structure with a resulting fire and significant electrical damage. There was no indication that CSST was a factor in the fire. The earth resistivity of the site was found to be a very low 2.09 ohm-m and the resistance to earth was found to be only 2.1 ohms.





Direct Strike at Corner of Building **Transition Between Gas Pipe and CSST**

A3.30 Place of event: North Charleston, SC / Date of event: August 4, 2009

Name of file:	Private communication
Title:	Private communication
Author:	Many authors + Mitch Guthrie
Date of publication:	
Place of event:	North Charleston, SC
Date of event:	August 4, 2009
Direct strike?	Probably
CSST bonded?	Yes (according to residents of other buildings in vicinity)
Electrical lines involved?	?
Comment	Direct strike with a bad high frequency grounding impedance.

Detailed investigation:

On Tuesday, August 4, 2009, this author was at the mail box at approximately 4:30 pm and noticed smoke coming from the roof vents in and around Unit 1402. I was never apprised of whether there was an actual fire or whether it was the smoldering CSST gas line burning the escaping gas.

The other units sustained smoke damage. Unit 1403 had air conditioning problems (reported to me in the week after the incident) for which I have not determined if the lightning was the cause. Unit 1401 sustained water heater area damage and the flex gas line needed repairs.

Later in the week, I talked with the plumbing company representatives in which they stated that they had replaced sections of flex gas lines in the attic, at the fireplace, and at the water heater. There was no indication how much gas line was actually replaced. They had generators and equipment at unit 1402 for approximately three weeks. The exterior of building 14 showed no signs of damage to the roof. This author is of the opinion that the side flash lightning strike hit the exhaust pipe on the roof and entered the attic flex gas line.

High frequency earthing measurements have been done at two locations in the condominium. One was carried out at a building near the damaged building (unit 33) and another one farer away (unit 8). At the first building the grounding was considered unsatisfactory, while at the second one grounding was considered satisfactory.

Below is an example of compared measurements at the ground rods at unit 8 and unit 33.

UNITS 8		UNIT 33	
FREQUENCY (HZ)	IMPEDANCE (OHM)	FREQUENCY (HZ)	IMPEDANCE (HZ)
79 HZ	1	79 HZ	1
250 HZ	1	250 HZ	Not Taken
1 KHZ	1	1 KHZ	Not Taken
5 KHZ	2	5 KHZ	1
10 KHZ	3	10 KHZ	Not Taken
25 KHZ	3	25 KHZ	3
40 KHZ	5	40 KHZ	5
63 KHZ	6	63 KHZ	8
80 KHZ	7	80 KHZ	8
100 KHZ	8	100 KHZ	11
125 KHZ	10	125 KHZ	12
156 KHZ	11	156 KHZ	14
199 KHZ	13	199 KHZ	16
250 KHZ	16	250 KHZ	19
316 KHZ	19	316 KHZ	22
398 KHZ	23	398 KHZ	32
500 KHZ	27	500 KHZ	32
633 KHZ	31	633 KHZ	36
797 KHZ	37	797 KHZ	77
1000 KHZ	48	1000 KHZ	73

Resistivity was also measured at unit 33 and was 27 ohm.m.

A StrikeNet report indicates that at around 5:00 pm, a 15 kA lightning strike was recorded in the vicinity of the damaged building. Another strike was recorded at same time a little farther away and was measured at 17 kA.

Mitch Guthrie added: After a significant storm, a neighbor noted smoke billowing out of vents on the roof. The fire did significant damage. Several holes were noted in CSST lines, according to the gas company. Significant damage was sustained, and it cannot be confirmed that there was a direct strike due to no eyewitnesses and destroyed forensic evidence. StrikeFax indicated a direct strike was possible.

In a single residential community consisting of two and four unit condominiums, there were four lightning-related incidents in a three day period of which two were confirmed CSST-related. All of the structures had been repaired, and the damaged CSST was not available for review from either site. The homeowner hosting the investigation indicated the local plumbers and gas company servicing the community indicated they had responded to 40 incidents of this type (there was no time frame given for this data).

The homeowner indicated that all residences in the community are basically identical. Each has gas fireplaces, furnaces, and water heaters. Gas and electrical service enter the structure at the same location for adjacent units. South Carolina Gas and Electric is distributed throughout the community in plastic pipe and transitions to "black pipe" as it exits the earth. The transition to CSST occurs in the wall after entering the structure. All units have three each 4-inch diameter metal vent pipes penetrating the roof. There are also numerous pine trees scattered throughout the community; especially around the perimeter.

One of the incidents resulted in a significant fire, and the other had a section of CSST breached with no resulting fire (see next case). Access to the damaged sites was not available, but the host homeowner did allow access to their home. Since all units were purported to be identical, electrical tests and visual inspections were conducted on this structure.

In the unit that experienced the fire, it was reported that “several holes” were found in a section of CSST, but it could not be confirmed the specific location of this section of piping.

A3.31 Place of event: North Charleston, South Carolina / Date of event: August 2, 2009

Name of file:	Private communication
Title:	Private communication
Author:	Many authors + Mitch Guthrie
Date of publication:	
Place of event:	North Charleston, South Carolina
Date of event:	August 2, 2009
Direct strike?	No
CSST bonded?	Yes (according to other buildings in vicinity)
Electrical lines involved?	Yes
Comment	Bad high frequency earthing.

Detailed investigation:

It was reported the damage to building 33 occurred at approximately 2:00 pm on Sunday, August 2, 2009. This is a 4-unit building in which unit 3201 sustained electronic damage to a computer, telephone, four televisions, and the garage door opener. No other gas line or other damaged was reported.

Unit 3202 sustained damage to the burglar alarm, telephones, and DVD Player, and a resident was shocked while ironing, with no damage to the gas lines.

Unit 3304 reportedly had a computer that was damaged, and no other gas lines or equipment were damaged.

Unit 3303 had CSST gas lines in the attic that were damaged and partially replaced by a plumber. The unit owner did not report any other damage when asked, other than that his answering machine was damaged.

High frequency earthing measurements have been done at two locations in the condominium. One was carried out at the damaged building (unit 33) and another one farther away (unit 8). At the first one the grounding was considered unsatisfactory, while at the second one it was considered satisfactory.

Below is given an example of compared measurements at the ground rods at unit 8 and unit 33.

UNITS 8		UNIT 33	
FREQUENCY (HZ)	IMPEDANCE (OHM)	FREQUENCY (HZ)	IMPEDANCE (HZ)
79 HZ	1	79 HZ	1
250 HZ	1	250 HZ	Not Taken
1 KHZ	1	1 KHZ	Not Taken
5 KHZ	2	5 KHZ	1
10 KHZ	3	10 KHZ	Not Taken
25 KHZ	3	25 KHZ	3
40 KHZ	5	40 KHZ	5
63 KHZ	6	63 KHZ	8
80 KHZ	7	80 KHZ	8
100 KHZ	8	100 KHZ	11
125 KHZ	10	125 KHZ	12
156 KHZ	11	156 KHZ	14
199 KHZ	13	199 KHZ	16
250 KHZ	16	250 KHZ	19
316 KHZ	19	316 KHZ	22
398 KHZ	23	398 KHZ	32
500 KHZ	27	500 KHZ	32
633 KHZ	31	633 KHZ	36
797 KHZ	37	797 KHZ	77
1000 KHZ	48	1000 KHZ	73

Resistivity was also measured at unit 33 and was 27 ohm.m.

A StrikeNet report indicates that at around 3:40 pm, a 20 kA lightning strike was recorded in the vicinity of the damaged building. Another strike was recorded at same time and was measured at 40 kA.

There is evidence that a tree was struck by lightning in the past and it is located 100 ft from building 33, near building 34 by the pond.

Mitch Guthrie added: Lightning apparently struck a tree in the vicinity of a structure that served as a quadraplex. There are four independent family dwellings in the single structure. As a result of the event, one unit experienced damage to a TV and other electrical items, in another a resident experienced an electrical shock while ironing, and a third reported no damage. The unit reporting the electrical shock while ironing also reported the smell of natural gas, but an investigation into his attic revealed no problem. He continued to smell the gas so he called the gas company. Upon investigation, it was found that there was a hole in a CSST line in the attic of the unit that reported no damage, where there was leaking gas but no evidence of a fire. The line was repaired without incident.

Annex 4: FOREIGN LITERATURE REVIEW

Information provided below comes from discussions with worldwide lightning experts. Additional data from local manufacturers are also included when available.

There is a European standard, EN 15266, "Stainless steel pliable corrugated tubing kits in buildings for gas with an operating pressure up to 0.5 bar", which was not provided to us at the time of writing the report.

UNITED KINGDOM

According to lightning protection experts, CSST is only used for short distances (typically 1 m) at interfaces between the gas distributor and the house installation. Also, its use for external applications such as caravans is mentioned.

According to one manufacturer, longer distances of CSST are also found in the UK.

In the UK, there is a standard for CSST, BS 5482-1:2005, "Code of Practice for domestic butane- and propane-gas-burning installations — Part 1: Installations at permanent dwellings, residential park homes and commercial premises, with installation pipework sizes not exceeding DN 25 for steel and DN 28 for corrugated stainless steel or copper."

BRITISH STANDARD

BS 5482-1:2005

Code of Practice for domestic butane- and propane-gas-burning installations —

Part 1: Installations at permanent dwellings, residential park homes and commercial premises, with installation pipework sizes not exceeding DN 25 for steel and DN 28 for corrugated stainless steel or copper

ICS 91.140.40; 97.100.20

British Standards

Facsimile of first page of BSI 5482-1

This standard deals only with supply from propane or butane cylinders. It should be noted that gas storage and distribution systems for multiple consumers are outside the scope of this standard.

However, regarding bonding, Clause 12.11 deals with the interrelation with other services. It is interesting to note that bonding to the electrical earth is mandatory and is intended to prevent sparks.

12.11.4 Main equipotential bonding (cross-bonding)

12.11.4.1 All gas installation pipework should be connected to the main earthing terminal of the electrical installation in accordance with BS 7671 (formerly known as the IEE Wiring Regulations).

NOTE: the purpose of electrical bonding is to create a zone in which voltage differences, and therefore hazards from electric shocks and sparks, are reduced. This is achieved by connecting separate conductive components together with suitable electrical conductors or via electrically continuous metal pipework. If an electrical fault occurs, either inside or outside of a building, it is possible for stray currents to be transmitted through the gas installation pipework. With a PME (protective multiple earth) system, a small current can pass along the pipework under normal conditions. Therefore, to avoid electric shock, or a spark which could ignite the gas, it is important to maintain electrical continuity in the pipework at all times and particularly when separating pipework and fittings

12.11.4.2 Main equipotential bonding should be connected:

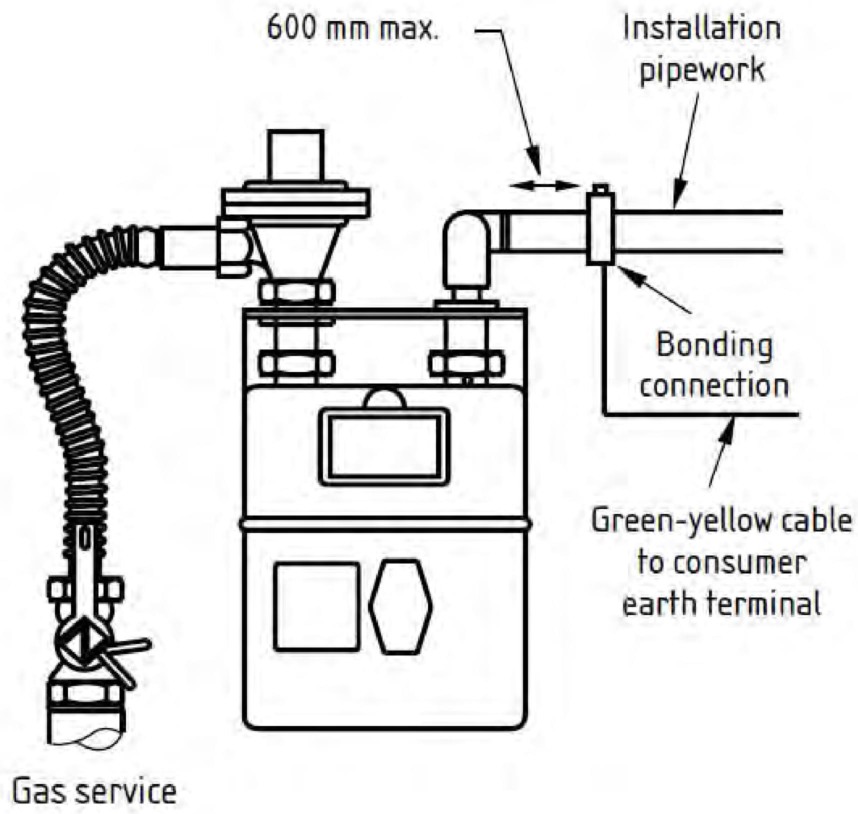
a) on the user's side of any meter or any insulating insert;

b) as close as practicable to the meter before any branch in the installation pipework;

c) in a position where it can be visually observed, with a warning label stating "Safety electrical connection. Do not remove"; and

d) on hard metal pipework by a mechanically and electrically sound connection which is not subject to corrosion (i.e. not exposed to the weather).

The main equipotential bonding of the gas installation pipework should be carried out using a flexible single-core multi-stranded copper-insulated conductor with a minimum cross-sectional area of not less than 10 mm2. The insulation should be the bi-color combination of green and yellow



Extract from BSI 5482-1

There is another standard, BS 7838, "Corrugated stainless steel semi-rigid pipe and associated fittings for low-pressure gas pipework of up to 28 mm," that was not provided at the time of writing this report.

Lightning protection experts, as well as the complete lightning protection committee, have been contacted to look for possible CSST lightning damages in the UK or in countries using UK standards.

Nothing has been reported.

One of the committee members provided the following note, which is quite meaningful:

1. the gas supply comes into the meter box in a plastic pipe. The plastic pipe is then joined to a short (about ¼ m) length of flexible piping, which appears to be a steel helix with plastic covering. This is then connected to a 'pressure regulator' on top of the meter. The gas supply then goes out from the meter in a solid-walled copper pipe. Clearly this is bonded or earthed in some way as a green and yellow covered cable then emerges close by.

2. Regulations.

Quotes from the 17th Edition wiring regulations BS 7671:2008

"411.3.1.2 Protective equipotential bonding

In each installation main protective bonding conductors complying with Chapter 54 shall connect to the main earthing terminal extraneous-conductive-parts including the following:

(i) Water installation pipes

(ii) Gas installation pipes

….."

544 PROTECTIVE BONDING CONDUCTORS

544.1. Main protective bonding conductors

“544.1.2 The main equipotential bonding connection to any gas, water or other service shall be made as near as practicable to the point of entry of that service into the premises. Where there is an insulating section or insert at that point or there is a meter, the connection shall be made to the consumer’s hard metal pipework and before any branch pipework. Where practicable the connection shall be made within 600 mm of the meter outlet union or at the point of entry to the building if the meter is external.”

Private Communication from One Member of BSI GEL 81

OMEGAFLEX in UK

Omegaflex UK supplies the UK market as well as Germany, Italy, France, and Greece. In the UK, 10 million feet of CSST have been produced. In the UK, not only short lengths of CSST exist, but long ones too. Pictures have been provided to illustrate the difference between the point of view of lightning expert and the point of view of Omegaflex. The main reason may be that the lightning experts were referring to domestic application, while pictures from Omegaflex depict industrial sites (see below).

Long Length of CSST Used in UK Provided by Omegaflex

[*13*: *2005 01 Omegaflex TracPipe Installation Guide 01-2005.pdf*]

No specific paragraph is dedicated to lightning protection in the Omegaflex TracPipe Installation Guide in Great Britain. Bonding is considered: All domestic gas installations shall have main equipotential bonding of the gas installation pipework conforming to BS 7671 (IEE Wiring Regulations). Separate conductive components must be connected together with earthing cable or metal pipework. To avoid electric shock, or a spark, which could ignite the gas, it is important to maintain electrical continuity in the pipework at all times.

Main equipotential bonding shall be connected:

a) on the customer's side of the meter

b) as close as practicable to the meter before any branch in the installation pipework

c) in a position where it can be visually observed, with a warning label stating 'Safety electrical connection. Do not remove'

d) by a mechanically and electrically sound connection which is not subject to corrosion (i.e. not exposed to the weather)

Main equipotential bonding of the gas installation pipework should be a minimum of 10 mm^2 cable with green and yellow insulation, construction reference 6491X conforming to BS 6004.

For internal meters, for verification purposes the bonding connection should be within 600 mm of the meter outlet.

For meters in outside meter boxes/compartments, the bonding connection should be preferably inside the building and as near as practicable to the point of entry of the installation pipework into the building. Alternatively, the connection may be made within the box/compartment, but it is essential that the bonding cable does not interfere with the integrity of the box/compartment and the sealing of any sleeve.

When relocating a meter, an existing main equipotential bond may be satisfactory as found, or it may need to be either lengthened or shortened or, in some cases, completely re-run.

CHINA

The CMA (meteorology administration in charge of lightning studies) is not aware of any CSST lightning damages, but fires are mainly addressed by the police. However, no lightning expert of CMA has been contacted to investigate an incident of lightning damage related to CSST.

Lightning experts are not aware of such problems.

CSST is massively used in CHINA for various purposes and is produced locally. 80% of CSST is used for gas distribution and 20% is used for water applications.

The following two Chinese manufacturers have been preliminarily contacted for this study; they are not aware of any cases of lightning damages to CSST. On the contrary, one expert declared that fires due to rubber tubes have pushed them to move to CSST.

- Taizhou Starofsky Pipe Industry Co., Ltd Zhongshan Village, Chumen Town , Yuhuan County, Taizhou, Zhejiang, China (mainland) 317605
- Tanggu Industrial Co., Ltd. Zhangguizhuang, Dongli area, Tianjin,China

The following additional companies have been contacted and found as manufacturers of CSST:

- Yuhuan County Juren Valve Factory
- Yuhuan Huasheng Plumbing Co.
- Ningbo Shengzi Import & Export Co.
- Ningbo Shengzi Manufacturing Co., Ltd.
- Ningbo Shengzi Pipelines Manufactory
- ZX Tianjin Tanggu Industrial Co., Ltd.
- Yuyao Lubu Kaixin Plumbing Pipe Factory
- Ningbo Shengzi

No answers have been received at date.

SOUTH AFRICA

There is no real gas supply network in South Africa, except in big cities such as Johannesburg. Cylinders are mainly used in the country, if any. Distribution is made with copper tubes.

Apparently CSST is not widely used. Lightning experts are not aware of CSST lightning problems

The Linrogas company has recently been contacted. It distributes Chufo CSST products. No answer has been yet received.

MALAYSIA

Apparently CSST is not used in Malaysia. Lightning experts there are not aware of any CSST lightning problems.

ITALY

Lightning experts in Italy are not aware of CSST lightning problems.

GERMANY

Lightning experts and contractors in Germany are not aware of CSST lightning problems there.

BELGIUM

Belgian lightning experts are not aware of CSST lightning problems.

BRAZIL

CSST is not used in houses in Brazil. Shielded conduit or plastic tubes are used.

Lightning experts in Brazil are not aware of CSST lightning problems.

GREECE

Apparently CSST is not used in Greece, and lightning experts there are not aware of CSST lightning problems. Omegaflex has provided us with pictures of industrial Greek sites using long lengths of CSS.

INDIA

Hydroflex Pipe, Ltd. has been contacted. No feedback has been received as of the date of this report.

FRANCE

In France, CSST has recently begun to be used. Named PLT in France, it is covered by Specification CCH 2007-01 and by construction requirement document DTU 61.1, “Installations de gaz dans les locaux d'habitation.”. Lightning experts in France are not aware of any CSST lightning problems.

CSST technology has been applicable in France, with specific termination fittings for French gas installations, since April, 2009. Two manufacturers have the ATG PLT mark (needed to be used) based on specification AFG CCH2007-01 and rules in ATG PLT.

These documents, as well as a list of products, are available on the Certigaz Web site: http://www.certigaz.fr/ . Products certified only since the second part of 2009 have been rarely used so far. Normally they should be used indoors. To supply installation, these PLT can be buried but not embedded in the house structure, except if they are run through a plastic pipe.

The specification for conductivity and bonding can be found inside a note. This specification requests that the manufacturer give advice regarding equipotential bonding to fulfill national requirements.

5.9 Prescriptions de conductivité électrique

Les composants du kit PLT doivent être électriquement conducteurs, voir 6.16.

NOTE Il convient que le fabricant conseille dans ses instructions d’installation qu’une liaison équipotentielle satisfasse aux réglementations locales.

Extract from AFG CCH2007-01

There is also a requirement for bonding, very similar to NFPA 54 except that there is no dimension given for the link. However, it is said that the bonding should be to the main electrical equipotential bar defined by NFC 15-100 (equivalent to the *NEC* in France).

The pipe cannot be used as a ground electrode.

9.7.1 Liaison équipotentielle

Les kits PLT, situés à l'intérieur des bâtiments ainsi que ceux placés à l'extérieur et faisant partie intégrante du bâtiment, doivent être connectés à la liaison équipotentielle principale (voir la NF C 15-100). Lorsque la canalisation pénètre dans le bâtiment, la liaison équipotentielle doit être effectuée en aval du raccord isolant PLT, s'il existe.

NOTE On entend par canalisation extérieure au bâtiment, une canalisation située en façade de bâtiment, par exemple une conduite d'alimentation chaufferie ou mini-chaufferie située en terrasse.

9.7.2 Prises de terre

Il est interdit d'utiliser les tuyauteries de gaz comme prise de terre.

Extract from AFG CCH2007-01

OMEGAFLEX in France

[*102*: *Guide d'installation TracPipe Banides.pdf*]

The installation guide requires that, in reference to the Unified Technical Document DTU 61.1, a bonding clamp be installed with a metal-to-metal contact onto the PLT AutoFlare fitting just after the entrance of the service into the structure.

SPAIN

Lightning experts in Spain are not aware of CSST lightning problems.

CANADA

Our contact in Canada has not provided data so far. Canadian lightning experts are not aware of problem of the same type as in the US, even if the product and their uses are similar.

SWITZERLAND

CSST is used in Switzerland. They are normally bonded between them, but not grounded to avoid a lightning current flow.

In principle, due to the absence of grounding, a spark to grounded part is possible, but this has not been reported so far.

SOUTH KOREA

In Korea, LPG (Liquefied Petroleum Gas) or LNG (Liquefied Natural Gas) is used in buildings.

CSST is used for gas water heaters. Water heaters are usually divided into two types:. one type uses electric power and the other uses gas for heating the water. CSST is not used for water, but for the water heater. Vinyl chloride hose is used for the gas supply underground. Aboveground, it is steel up to the private installation. CSST is used for short distances only. A metal vent from heaters goes outside. There may be a long length of steel outside and a short distance between the steel and the vent outside. In Seoul and other big cities, buildings are as high as 40 m. In other cities, buildings are typically 10-15 m high. Some companies ask for bonding of steel to ground at the interface of underground isolating pipe and overhead steel pipe.

View of Gas Pipe on Right and Vents (One at Each Apartment)

View of CSST (in Orange)

There were several cases of gas leakage in CSST, but the causes of the gas leakage were not clear. It could not be established whether they were related to lightning damage or to mechanical damage.

Three companies have been contacted in South Korea:

- Dong-A Flexible Metal Tube Co., Ltd.
- Kofulso (Headquarters of EasyFlex)
- Royal Metal, Inc., Jeongwang-dong, Siheung-si Gyeonggi-do

Only Royal Metal, Inc. provided us with relevant pieces of information. [*131*: *Royal Metal - Jay Moon - Mail.pdf*] The problems with CSST are described to be identical in South Korea to those in the USA. However, considering the technical background and the limited CSST experience of our contacts in Korea, further investigation might be necessary to ascertain the exact similarity. A leakage problem exists, which is being resolved; no information has been provided on the exact circumstances of the leakage occurrences.

Facsimile of First Page of RoyalFlex Catalogue

Regarding the leakage, we got the following feedback:

"For preventing the damage, we are trying to remove the construction of gasket from the gas tube. Instead of gasket, the flare part from the tube is formed of one body type for preventing the leakage of gas from the tubing."

There are standards in Korea dealing with CSST (not all have been analyzed). Some are listed here:

- Code KGS GC252 2009 : Code for Construction Supervision of Urban Gas Supply Facilities
- Code KGS FS551 2010 Facility/Technical/Inspection Code for Pipes Outside of Producing and Supplying Places of Urban Gas Business
- Code KGS FS552 2009 Facility/Technical/Inspection Code for Governors of General Urban Gas Business
- Code KGS FU551 2010 Facility/Technical/Inspection Code for Urban Gas Using Facilities
- Code KS D 3628 : 2004 (Confirmation in 2005) Stainless steel flexible pipes
- Code KS D 3625 : 2008 (Confirmation in 2008) Metallic flexible hoses for gas with the following tests:

  11.3 Capability test of hose

  11.3.1 Tightness test

  11.3.2 Internal pressure test

  11.3.3 Tensile test

  11.3.4 Twisting test

  11.3.5 Curvature test

  11.3.6 Impact test

  11.3.7 Repeated attachment test

  11.3.8 Heat resistance test

  11.3.9 Stress corrosion split test

  11.3.10 Flux test

  11.3.11 Flexibility test

  11.3.12 Liquidity test

  11.3.13 Inflammation test

  11.3.14 Hot-cold cycle test

11.3.15 All weather test

11.3.16 Drawing test

11.4 Gas-proof test of gasket

11.4.1 n-pentane test

11.4.2 Butane test

JAPAN

Japan is using CCST. The process of manufacturing CSST consists of a series of linear operations. The process starts with rolls of stainless steel. Unrolled, the metal sheet is formed into a tube. The tube is welded. The quality of the welding is automatically and continuously controlled. The tube is then corrugated. It undergoes a heat treatment, followed by a leak test. It is then coated with polyvinyl chloride. The tube is finally marked and coiled.

The Japanese CSST manufacturing companies that have been contacted include JFE Steel, Osaka Steel, Tokyo Steel, Kawasaki Steel, Hitachi Metals, and Chufo. The information received has unfortunately been of limited value.

Below is the copy of two pages in Japanese obtained from the lightning experts. One page deals with the problem encountered with the gas pipe and information regarding lightning. The other page is instructions on how to install CSST. Partial translations are provided beneath each page. Even if the lightning experts are not aware of any lightning problems with CSST, it seems that there are some restrictions for use of CSST in Japan.

2006/3/28 和歌山和歌山市０００ 大阪ガス株式会社　一般
建物近辺への落雷による影響でフレキ管に孔が開き、漏えいしたガスに着火したものと推定。床下の一部を焼損。
漏洩着火　自然現象

2006/7/14 千葉佐倉市０００ 角栄ガス株式会社　一般
需要家宅付近で激しい落雷があり、床下基礎コンクリート鉄筋露出箇所近傍のフレキガス管が、落雷の影響と思われる電流等の影響を受け損傷し、着火したものと推定。床下断熱材を一部焼損。
漏洩着火　自然現象

2006/7/15 京都宇治市０００ 大阪ガス株式会社　一般
埋設灯内内管から家屋へ引き込む立ち上がり部の灯内内管 (鋼管、口径 25mm) に落雷により約２ｍｍの孔が開き、漏えいしたガスに着火。外壁の一部を焼損。
漏洩着火　自然現象

2006/8/17 新潟三条市０００ 北陸ガス株式会社　一般
落雷により、建物基礎貫通部のフレキ管 (25ｍｍ) が損傷し約 4～6ｍｍの孔が開き、漏出したガスに着火。フレキ管及び床下木材が一部焼損。
漏洩着火　自然現象

漏洩着火　2006 年　62 件発生　　2002～2006 年では 171 件

出典：
２００６年都市ガス事故報告の概要
平成１９年６月２５日
原子力安全・保安院　ガス安全課

2010 年事故速報　（原子力保安院 HP）
（LPG）　７月３日 山口県 ０００ 共同住宅において、住人が外出中に、同宅の寝室の床の一部から出火し、同宅の一部を焼損する事故が発生した。原因は、火元となった部屋の床下に敷設された供給管（金属フレキ管）に穴（ピンホール）が生じ、そこからガスが漏えいし、何らかの火が引火したものと推定されるが、現在詳細調査中。　金属フレキ管 調査中

Facsimile of Japanese Lightning Expert Documentation – Page 1

Partial translation :

Title: **Outage Example Due to Lightning** (it is not sure that all damages were related to flexible pipes)

28/3/2006 A hole in a flexible pipe was made due to lightning strike close to a building. After this, leaking gas was ignited.

19/7/2006 A flexible gas pipe was damaged by lightning current and was ignited.

15/7/2006 Installation supplied by an iron underground tube. A 2 mm hole was created inside the house due to lightning and leaking gas was ignited.

17/8/2006 A 4 to 6 mm hole was created at the house entry point due to lightning and leaking gas was ignited.

3/7/2010 A pinhole was created inside the house and leaking gas was ignited.

INFO from JFE http://www.jfe-steel.co.jp/products/koukan/catalog/e1j-013.pdf

1. 施工上の注意事項

ステンレス鋼フレキシブル管（フレキ管）を正しく安全に施工していただくだめに、次の事項をお守りください。

●施工者の資格

フレキシブル管を施工するには、それぞれ次の資格が必要です。

①LP ガスの場合：液化石油ガス設備士でかつフレキシブル管作業者講習を修了した者。

②都市ガスの場合：各都市ガス会社により、認定された者。

●施工場所の限定

（1）用途の制限

フレキシブル管はガス専用です。水や油、温水等には絶対に使用しないでください。

（2）施工場所

フレキシブル管は末端閉止弁までの低圧部に使用します。

（3）配管禁止場所

次の場所での配管は禁止です。

①高温・高圧となる可能性のある場所

②増設配管で、フレキシブル管や配管モールの固定ができない場所

③フレキシブル管が容器交換時に損傷を受ける恐れのある場所（LPG の場合）

④配管が人や車両等によって踏まれたり、潰されたりする可能性が高い場所

⑤配管に振動、衝撃が加わる場所

⑥土中、コンクリートの直埋設部

⑦ケーブル線や電気配線等と接触する場所

●フレキシブル管取扱い時の注意

①最小曲げ半径（P. 14 参照）を守り、それ以下の半径で曲げないでください。

②管をねじったり、必要以上に引っ張ったりしないでください。

③管に強い衝撃を与えたり、踏み付けたりしないでください。

④変形防止のため、管の切断面には絶対に触れないでください。また、手など損傷する恐れがありますので注意してください。

⑤被覆の疵付きに特に注意し、被覆の穴明きは必ず目張り等の補修をお願いします。湿潤雰囲気での被覆穴明き疵は、フレキシブル管を腐食させる原因となることがあります。

⑥釘打ちやカッターなどの刃物によるフレキシブル管穴明きにご注意ください。そのような恐れのある場所の配管は極力さけるか、やむを得ない場合は何らかのプロテクターをご使用ください。

⑦ステンレス鋼といえども腐食することがあります。塩素イオンその他の腐食原因にご注意ください。

⑧落雷や過大な熱源により管壁が溶損することがあります。施工場所や工事周辺状況に充分ご注意ください。

Facsimile of Japanese Lightning Expert Documentation – Page 2

Partial translation :

Title: **Notice for Construction Engineers of Flexible Gas Pipe**

Prohibited places: Connection places with cables wire and electrical power lines

“8”: there is some possibility for a lightning strike to make a hole in the tube. Please be careful of the construction place and environment.

PAKISTAN

Ojus Overseas has been contacted. No answers have been received as of the date of this report.

RUSSIA

The Kofulso/EasyFlex branch in Russia has been contacted. No answers have been received as of the date of this report.

TAIWAN

The company Elitre Co., Ltd. has been contacted, but they are not willing to share technical information.

TURKEY

The company Emin Teknik, Ltd. has been contacted. No feedback has been received yet.

UKRAINE

The Kofulso/EasyFlex branch has been contacted in the Ukraine. No answer so far.