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Gas Lines and Electricity

Cedar Hill, Texas

March 11 2016

Mark Goodson PE

1500 Spencer Rd ● Denton TX 76205

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Rules

- All questions are good
- No taping or recording

- COI Statement

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Inspection Issues

- Key questions

- When installed?
- Were additions or repairs made?
- What version of code was in effect?
- Is ‘present’ code compliance desired?

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Bonding and Grounding

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- Required under NEC

- Purpose is to prevent electrical shock
- Second purpose is to prevent arcing
- Tying all things together creates same voltage (or does it?)

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Bonding and Grounding

- Key phrase with piping…
- Piping that is likely to be energized
- That means gas water heaters, gas grills, and chimneys have not historically required bonding – they have no source of energization

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Bonding and Grounding

- ALL CSST must be bonded
- #6 wire must be used
- This includes water heaters, FPs and grills
- Bonding to run from hard black pipe at house entry to electrical system ground
- Per NFGC 2009 Article 7.13

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NFGC 2015

- Requires bonding
- Bonding jumper < 75’
- Bonding at service entrance not necessary

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NFGC 2006

- Bond all gas equipment likely to be energized
- Bonding is considered done when an electrical appliance that uses gas is plugged in the wall (EGC bonding)
- THIS system provides shock protection

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NFGC 2018

- Go to NFPA.ORG
- Look up NFPA 54

- NUMEROUS changes proposed related to CSST, bonding, routing, etc.

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Public Input 59

- ROUTING OF BONDING CONDUCTORS
- Conductors used for bonding CSST shall be installed in accordance with NFPA 780, *Lightning Protection Systems*, and shall specifically have bending radii and angles of inclusion as specified by NFPA 780 4.9.5

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Public Input 62

- CSST gas piping systems, and gas piping systems containing one or more segments of CSST, shall be bonded to the electrical service grounding electrode system or, where provided, lightning protection grounding electrode system.
- No instruction or literature from a CSST manufacturer shall infer or imply that this additional bonding as described above is not needed.

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Public Input 64

- Bonding connections shall be in accordance with *NFPA 70, National Electrical Code*.
- Installation of CSST shall not cause a violation of NFPA 70 (National Electric Code).

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Public Input 69

- Corrugated stainless steel tubing shall be listed in accordance with ANSI LC 1/CSA 6.26, *Fuel Gas Piping Systems Using Corrugated Stainless Steel Tubing.*
- *Only CSST that is capable of passing Standard LC - 1027 (PMG Listing Criteria for Conductive Jacketed Corrugated Stainless Steel Tubing) as modified here shall be installed.*

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Public Input 144

CSST gas piping systems, and gas piping systems containing one or more segments of CSST, shall be bonded to the electrical service grounding electrode system or, where provided, lightning protection grounding electrode system.
Exception: Bonding shall not be required where CSST is installed in accordance with the CSST manufacturer's instructions and the terms of its listing.

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Public Input 162

- Change jumper length
- Testing was wrong
- No peer review
- GTI report resistance is wrong

- VERY long commentary – read the report

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Gas Appliance Connectors

- ANSI Z21.24
- Lengths 3 to 6’
- Brass or SS
- Intended for single use
- Often coated to prevent corrosion

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Mfrs of GACs

- Brass Craft
- US Brass
- Dormont
- Robert Mfg

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Contact Information

- Dormont Manufacturing Company
- 6015 Enterprise Drive
- Export, PA 15632
- 800.DORMONT
- info@dormont.com
- www.dormont.com

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Contact Information

- BrassCraft Manufacturing Company
- 39600 Orchard Hill Place
- Novi, MI 48375-5331
- 248.305.6000
- customerservice@brasscraftthq.com
- www.brasscraft.com

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Gas Appliance Connector Commercial

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GAC FAILURES

- First written on January 1999
- *Fire & Arson Investigator*

- Authored by Mark Goodson

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GAC FAILURES

- Example:

- AC Compressor shorts out
- Fault current up Cu lines to evaporator
- Current then goes to furnace
- Current then from furnace to gas line
- Gas line then fails
- Failed gas line is a torch

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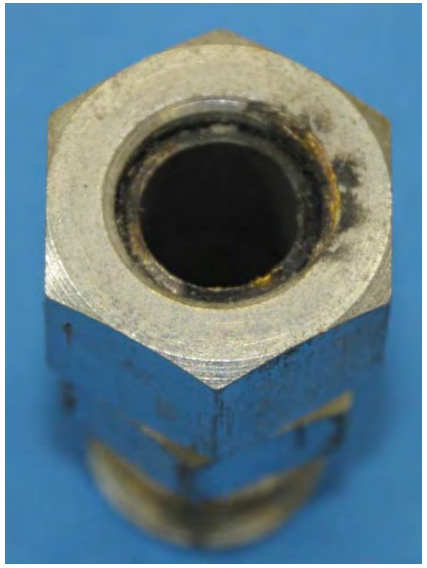
Gas Appliance Connector



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Gas Appliance Connector

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Failed GAC after lightning

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Damaged vent

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GAC Failure Flare end arced off

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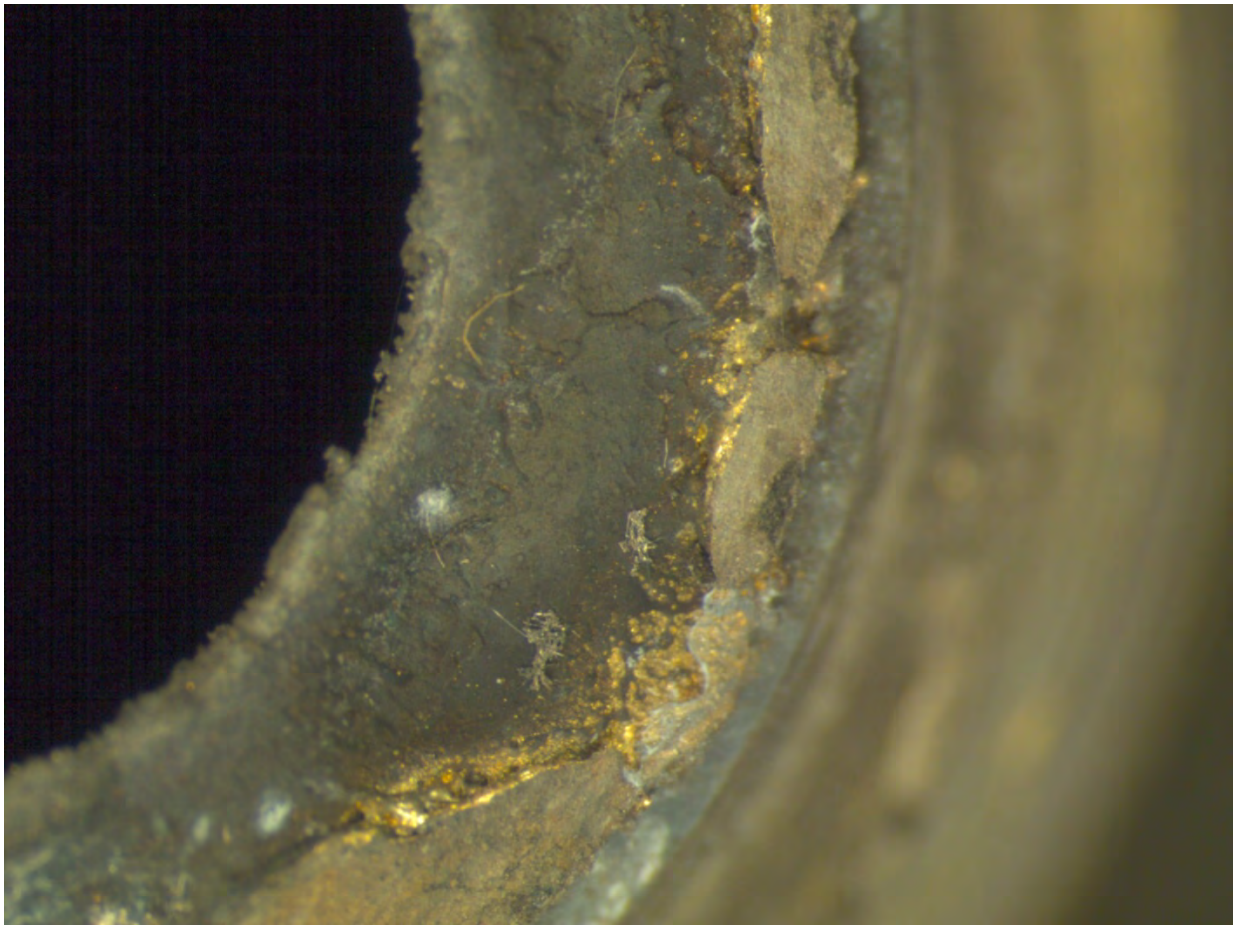

GAC Failure - Melted brass on Male Flare Adapter

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GAC FAILURES

- Lightning
- Failed AC compressors
- Tree trimming, with limbs getting into power lines

- Our lab – 120 failures in 30 years

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GAC Fire #1

- Gas Appliance Connector End Failed
  - 8 Million Dollar Loss
  - Lightning Activity
  - AC Compressor Grounded to Energize Gas Line

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GAC Fire #1

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GAC Fire #1

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GAC Fire #2

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GAC Fire #2

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Excess Flow Valves

- Work similar to a circuit breaker
- Shuts off gas if flow rate exceeds set value
- Great for seismic regions that could have gas lines sheared
- Gas line punctures produced by arcing have flow rates in line with gas appliances

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Excess Flow Valves

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Excess Flow Valves

- Do they work?
- Will a leak in CSST be detected?
- How sensitive are the valves to small leaks?

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Excess Flow Valves

- Work roughly 200 to 300 K BTU / hr

- IE – Fractured gas line
- We have seen typical leaks on CSST at 20 to 30 K BTU / hr
- This is a 30 gallon water heater cycling
- Useless for lightning perforated CSST

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Bonding Jumper

- Clearly issue is keeping current off of gas line and flare

- A bonding jumper would accomplish this.

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Bonding Jumpers

- See US Patent 7,562,448
- Also US Patent 7,821,763

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Need for GAC Jumper

- Energized ground
- Floating neutral
- Hot to ground fault
- Lightning

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Figure 6A CSST with Single Grounding Wire

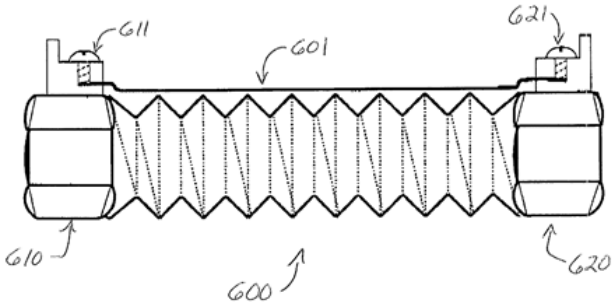
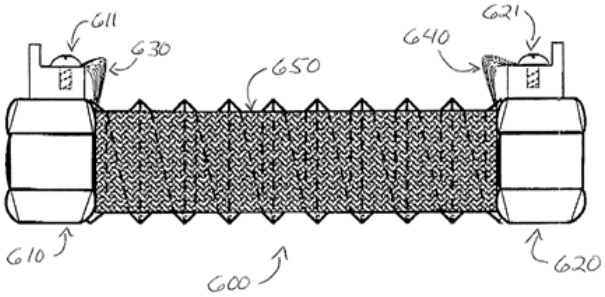


Figure 6B CSST with Multiple Strands of Grounding Wire



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Jumper testing

- Jumper makes a shunt
- Depending on wire gauge and GAC composition
- - testing shows current on flares drops to 3 to 5% of original current

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Patent info

- Goodsonengineering.com
- PUBLICATIONS
- Device for Preventing Electrically Induced Fires in Gas Tubing
- Method of Preventing Electrically Induced Fires in Gas Tubing

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Lots of Change

- ***250.2 DEFINITIONS***
- ***Effective Ground-Fault Current Path*** *An intentionally constructed low-impedance electrically conductive path designed and intended to carry current under ground-fault conditions from the point of a ground-fault on a wiring system to the electrical supply source and that facilitates the operation of a overcurrent protection device or ground-fault detectors on high-impedance grounded systems.*

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Lots of Change

- ***Ground Fault*** *An unintentional, electrically conducting connection between an ungrounded connector of an electrical circuit and the normally non-current carrying conductor metallic enclosures, metallic raceways, metallic equipment, or earth.*

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Lots of Change

- *FPN: Examples of ground-fault current paths that could consist of any combination of equipment grounding conductors, metallic raceways, metallic cable sheaths, electrical equipment, and any other electrically conductive material such as metal water and* ***gas piping****, steel framing members, stucco mesh, metal ducting, reinforcing steel, shields of communications cables, and the earth itself.* **(Emphasis added)**

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Lots of Change

- ***Ground-Fault Current Path*** *An electrically conductive path from the point of a ground-fault on a wiring system through normally non-current carrying conductors, equipment, or the earth to the electrical supply*

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Lots of Change

- *250.4A(4)* ***Bonding of Electrically Conductive Materials and Other Equipment*** *Normally non-current carrying conductive materials that are likely to become energized shall be connected together and to the electrical supply source in a manner that establishes an effective ground-fault current path.*

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Lots of Change

- *250.4A(5)* ***Effective Ground-Fault Current Path*** *Electrical equipment and wiring and other electrically conductive material likely to become energized shall be installed in a manner that creates a low impedance circuit facilitating the operation of the overcurrent device or ground detector for high-impedance grounded systems. It shall be capable of* ***safely*** *carrying the maximum ground fault current likely to be imposed on it from any point on the wiring system where a ground fault may occur to the electrical supply source. The earth shall not be considered as an effective ground path.* [11]
- **(Emphasis added)**

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Lots of Change

- What is the change?
- The NEC has NOT changed

- A loose wire that contacts a gas pipe should cause the breaker to immediately trip

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GTI Report on CSST Table 3

Mfr	CSST Diameter (Inches)	DC Resistance milliohm/ m	DC Resistance, milliohms / ft (Derived by authors from SI units)
A	.5 1	7.13 4.33	2.17 1.32
B	.5 1	19.91 4.75	6.06 1.45
C	.5 1	7.29 4.72	2.22 1.44
D	.5 1	7.35 4.35	2.23 1.32

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What is wrong?

- Brand A C and D
- GTI says ~ .0022 ohms per foot
- GTI report understates values by a factor of 10
- One cannot consider CSST as an effective ground path

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What is wrong?

- Under some length and breaker combinations – a breaker will not trip timely (or at all)

- The jacketing can instantly have issues
- (See presentation of Mr. Colwell)

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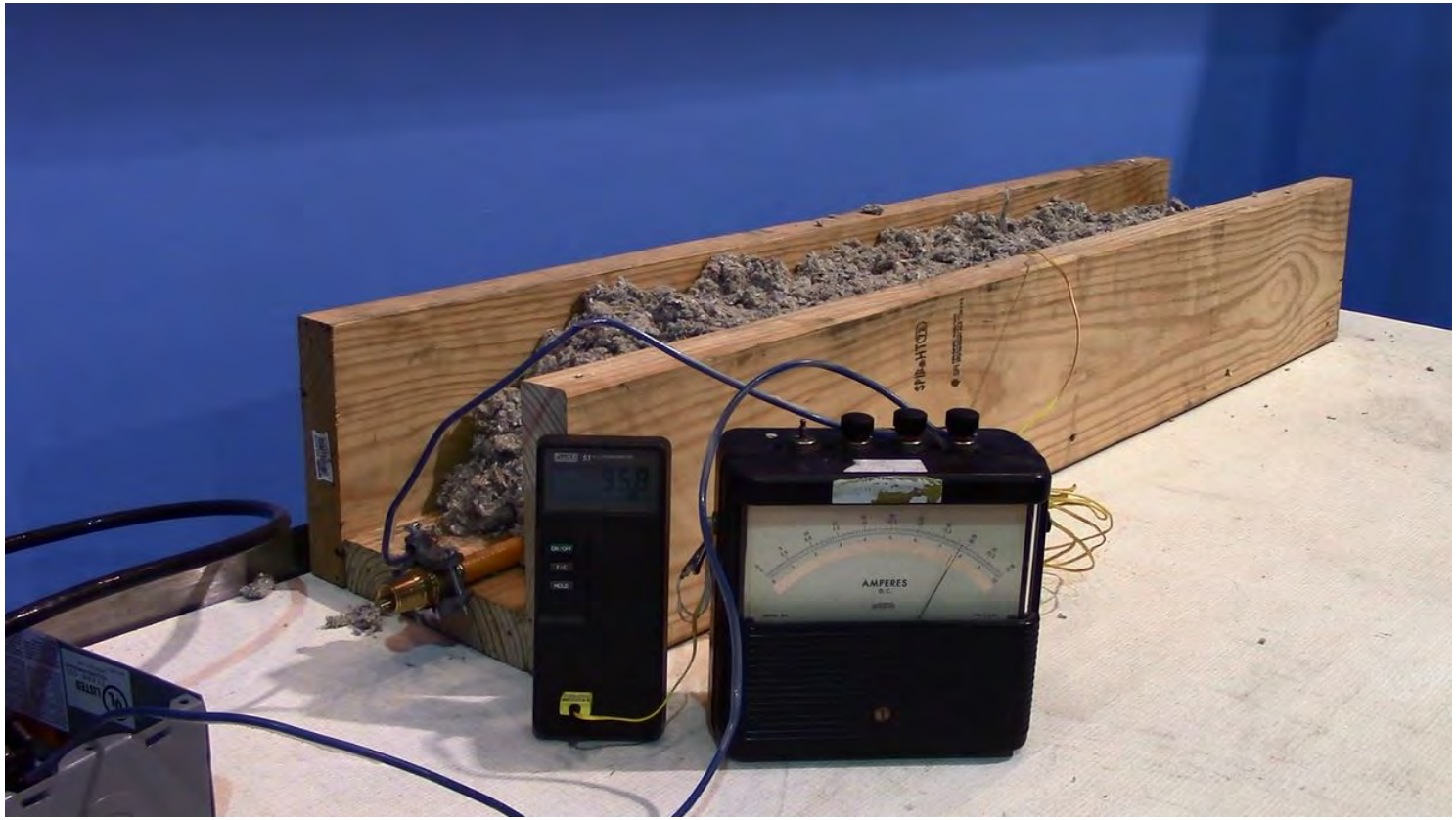

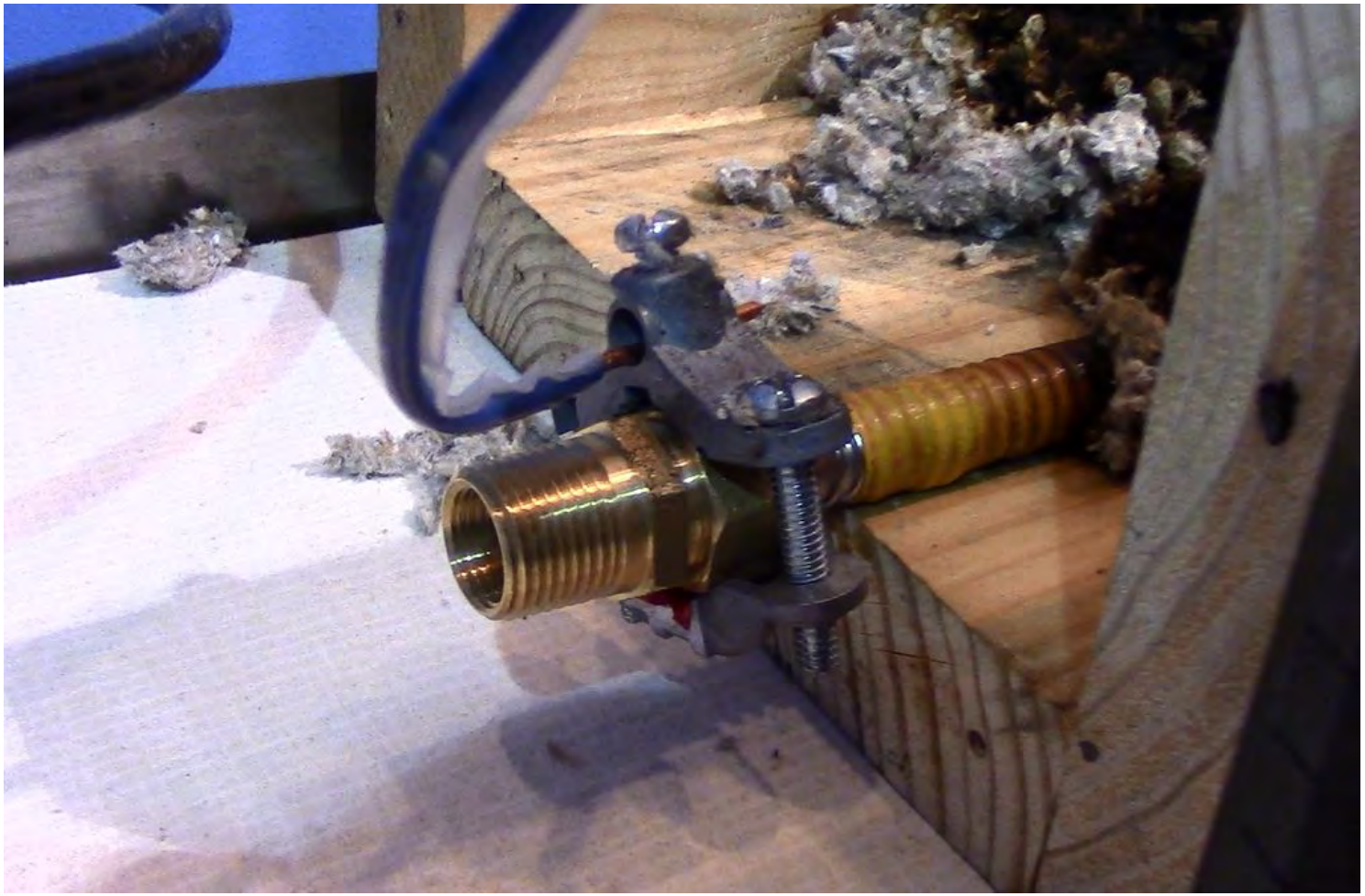

35 amperes constant current

Protected by 40 amp breaker

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Obvious smoke

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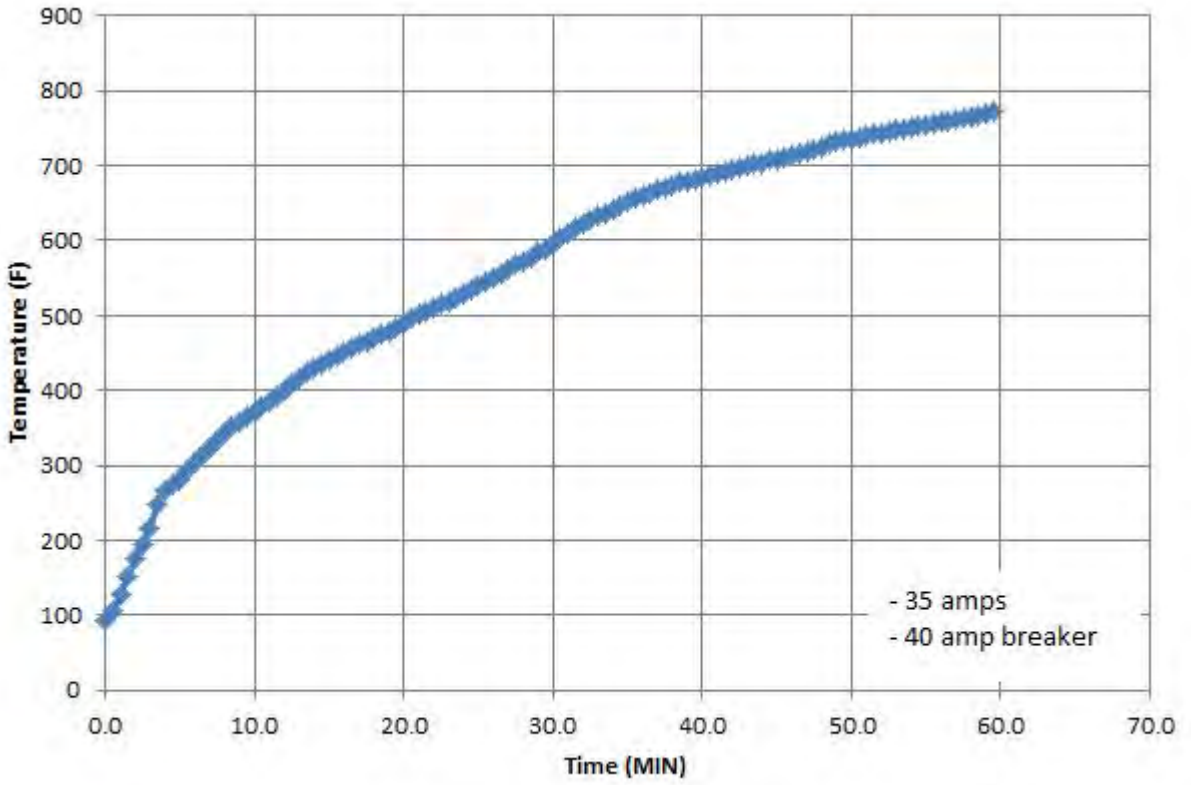

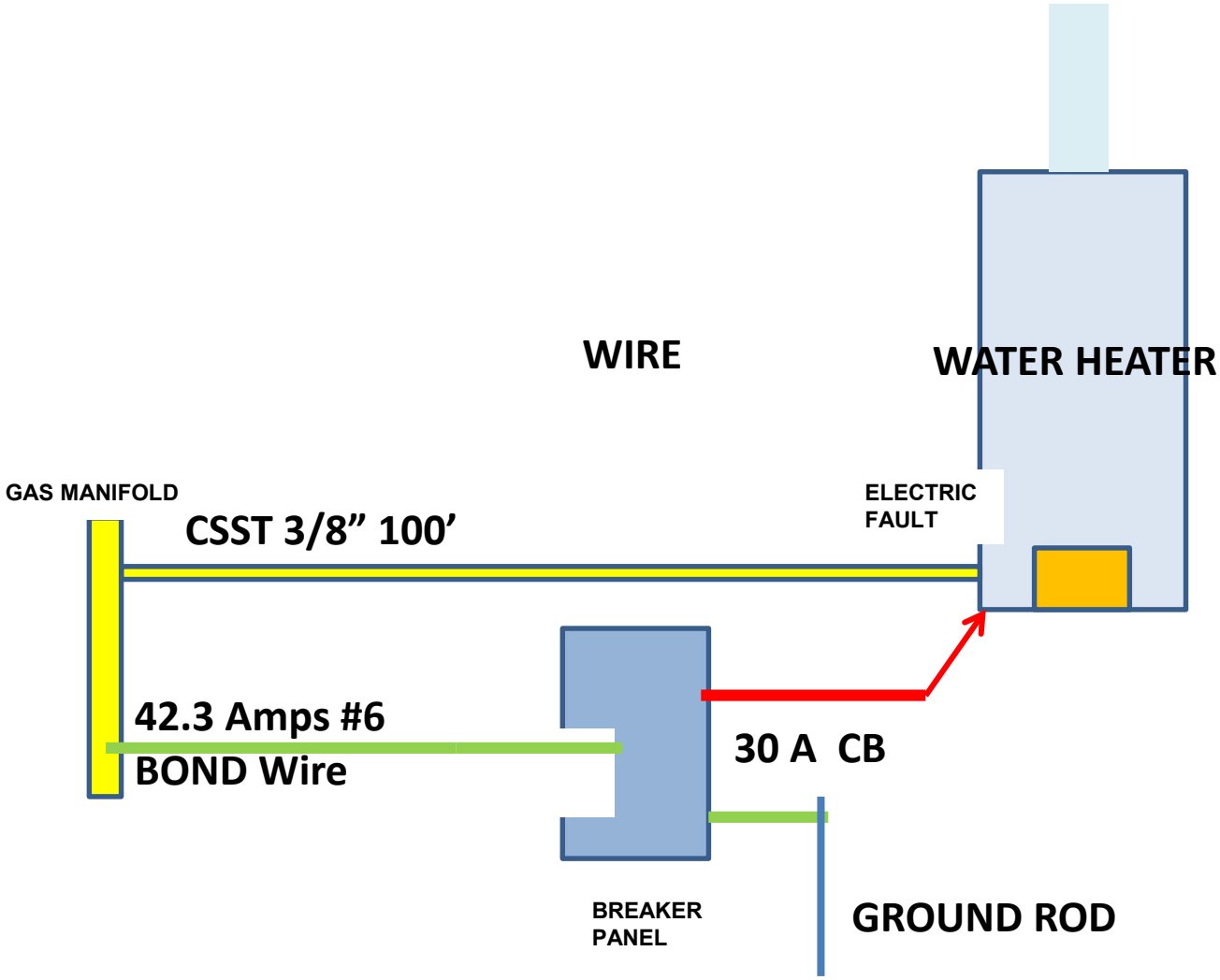

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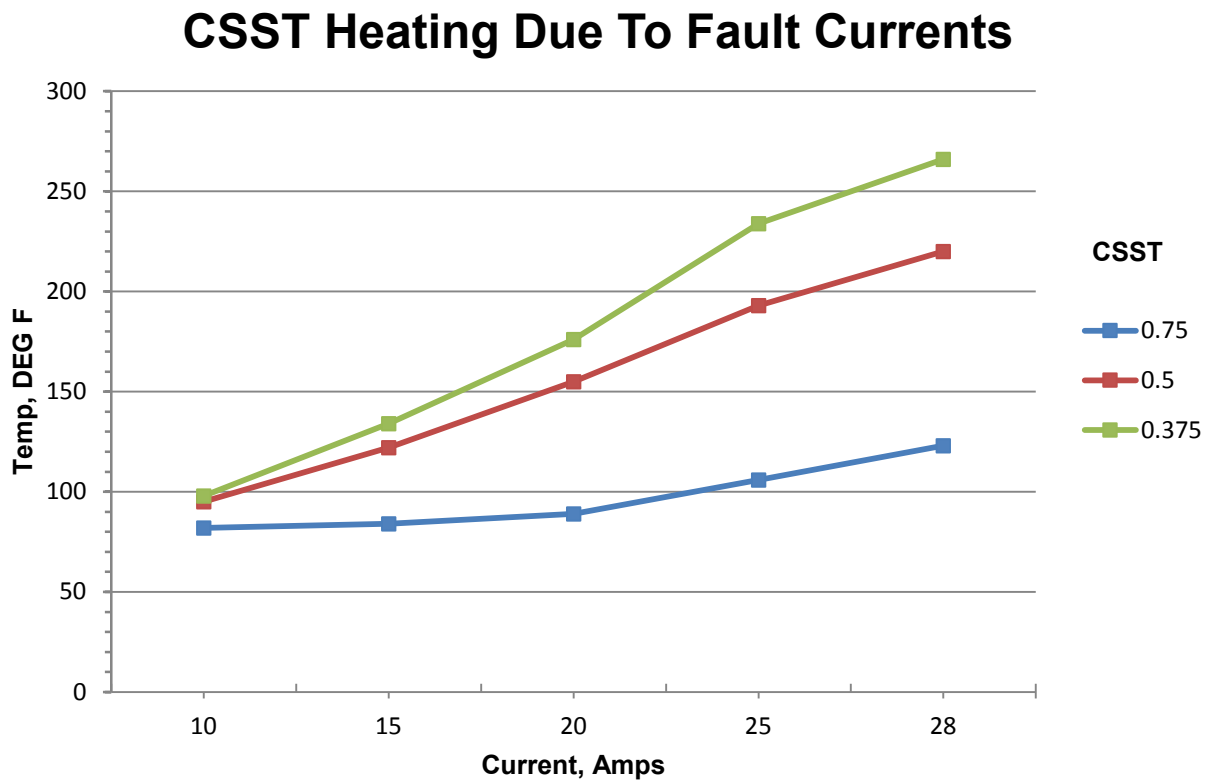
What is wrong?



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End result?

- CSST can result in ground faults not being cleared
- CSST can overheat under ground faults
- CSST is a shock hazard
- Recent NFPA reliance on GTI report is misguided

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The NEW GTI Report

- *This revision of the report is being issued in order to address a number **of typographical errors** that were discovered in the original version. Specifically, the **resistance per meter of various CSST products as measured by Lightning Technology Incorporated were an order of magnitude too low** as shown in the original report. This revision effects Table 3 in the main body of the report and Table 6 – CSST per Unit Length Resistance, Inductance, and Capacitance in Appendix B provided by LTI. The corrected values are exactly a factor of ten larger than those from the original report, eliminating the typographical error. If one examines Table 5 – Resistance, Inductance, and Capacitance Measured on 2-meter CSST Samples from the LTI report it is seen that the raw data is correct and the error was introduced when the raw data was normalized to one meter lengths.*

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This is ALL new data

- You heard it here first

- Respond to NFPA proposals as your conscience dictates

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CSST

- 1988 brought to market
- No EE on staff during development
- No electrical testing
- History of trying to ‘fix’ code rather than product
- Industry devised their own spec – ANSI LC-1

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Flammability Tests
Steiner Tunnel

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- Steiner Tunnel – Developed in 1943 by Underwriter's Laboratories Engineer A.J. Steiner

- ASTM E-84 (NFPA 255) – Standard test method for surface burning characteristics of building materials.

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Flammability Tests
Steiner Tunnel

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Flammability Tests
Steiner Tunnel

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- Specifications
  - 25 Feet Long
  - 18 Inches Wide
  - 3.8mm Water Column draft
  - 5,000 BTU/minute Natural Gas Flame, 1 Foot from end
  - Material suspended from ceiling

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Flammability Tests
Steiner Tunnel

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- Flame Spread Rating
  - Zero point – Noncombustible cement board
  - 100 – Red Oak Flooring, 5-6 minutes to travel 25 feet (flame spread can be higher or lower)

Class	Flame Spread	Smoke Developed
A	0-25	0-450
B	26-75	0-450
C	76-200	0-450

- BOCA National Building Code and Uniform Building Code use I, II, and III.

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Flammability Tests
UL 94

- UL94 serves as a preliminary indication of a plastic's acceptability for use as part of a device or appliance with respect to its flammability (CSST outer jacket)

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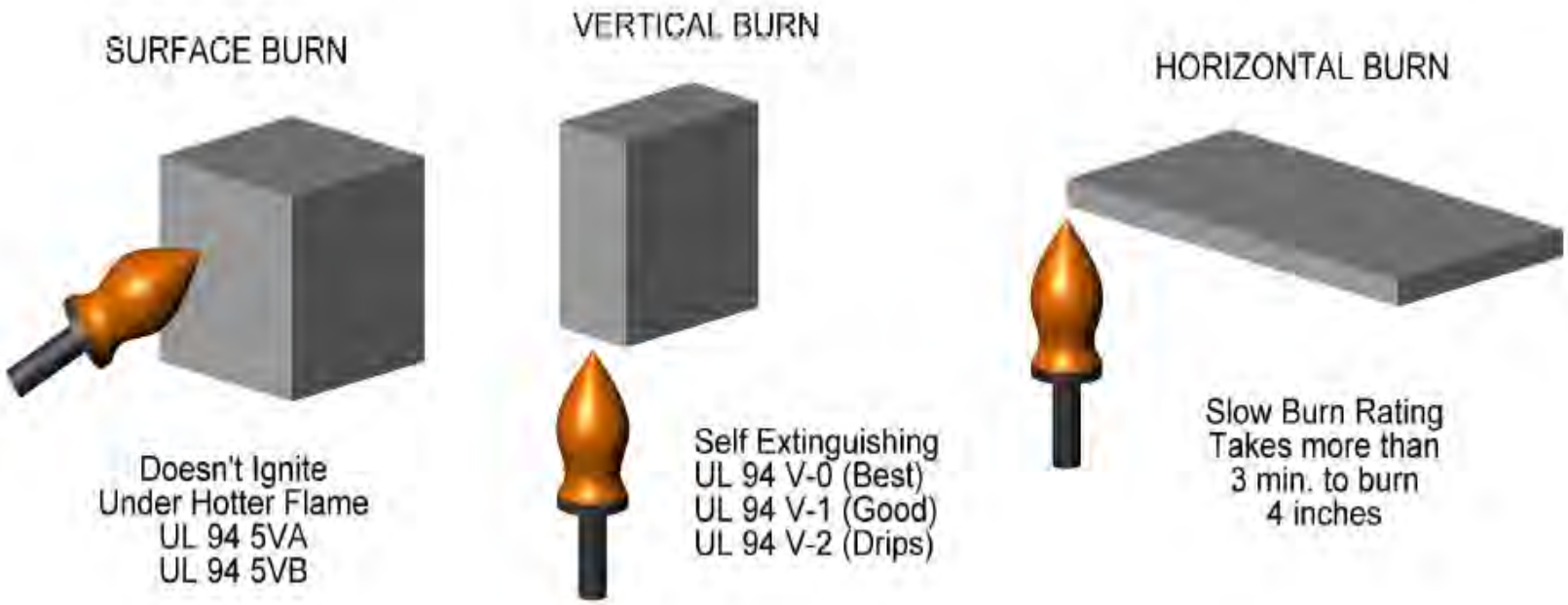
Flammability Tests

UL 94

UL94 – Burn testing methods



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Flammability Tests
UL 94

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UL 94 Flammability Rating Summary	
5VA Surface Burn	Burning stops within 60 seconds after five applications of five seconds each of a flame (larger than that used in Vertical Burn testing) to a test bar. Test specimens MAY NOT have a burn-through (no hole). **This is the highest (most flame retardant) UL94 rating.**
5VB Surface Burn	Burning stops within 60 seconds after five applications of five seconds each of a flame (larger than that used in Vertical Burn testing) to a test bar. Test specimens MAY HAVE a burn-through (a hole).
V-0 Vertical Burn	Burning stops within 10 seconds after two applications of ten seconds each of a flame to a test bar. NO flaming drips are allowed.
V-1 Vertical Burn	Burning stops within 60 seconds after two applications of ten seconds each of a flame to a test bar. NO flaming drips are allowed.
V-2 Vertical Burn	Burning stops within 60 seconds after two applications of ten seconds each of a flame to a test bar. Flaming drips ARE allowed.
H-B Horizontal Burn	Slow horizontal burning on a 3mm thick specimen with a burning rate is less than 3"/min or stops burning before the 5" mark. H-B rated materials are considered "self-extinguishing". **This is the lowest (least flame retardant) UL94 rating.**

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Flammability Testing

PVC Schedule 40 Being Burnt

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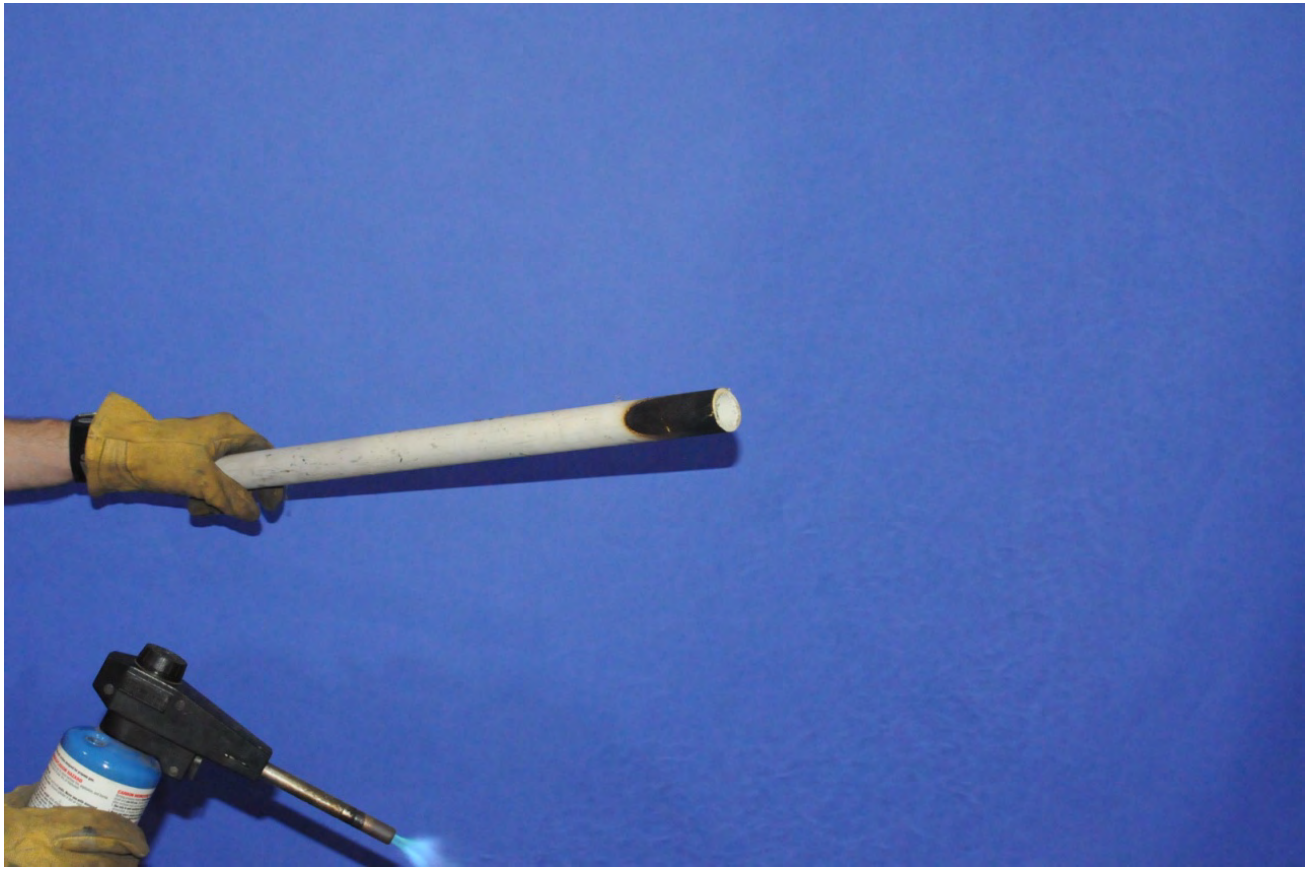

Flammability Testing

PVC Schedule 40 - Extinguished immediately after flame removed

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Flammability Testing

Romex NM Being Burnt

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Flammability Testing

Extinguished Immediately after flame removed

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Flammability Testing

CSST Being Burnt

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Flammability Testing

Picture of CSST - 5 seconds after flame removal

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Flammability Testing

CSST - 10 seconds after flame removal

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Flammability Testing

- Why Steiner Tunner?
- Why not UL 94/1581?

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CSST Fire Example

- This was not an energized gas line fire, but the CSST jacketing did spread the fire.

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CSST Fire Example

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CSST Fire Example

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CSST Fire Example

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CSST Fire Example

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CSST Fire Example

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CSST - History

- 1988 - CSST developed for commercial use by Foster- Miller
- 2003 – CSST approved by the International Association of Plumbing and Mechanical Officials (IAPMO)
- 2009 – CSST gas piping systems shall be bonded to the electrical service grounding electrode system at the point where gas service enters the building

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CSST - History

- Advantages of CSST over Black Pipe
  - Low sensitivity to structural shifting
  - Fewer connections
  - Labor savings
    - No threading of pipe
    - Less planning , measuring and cutting
    - Easy to route
  - No splices
  - No Joints behind walls that might fail
- Disadvantages of CSST
  - One run per appliance required from manifold, increases the number of feet of piping in one household

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CSST Manifold

CSST – Manufacturers

- Six manufacturers of CSST
  - Ward Manufacturing
  - Parker Hannafin (No longer makes)
  - Smiths Tubular Systems - Titeflex
  - Omega Flex
  - Tru-Flex
  - Metal-Fab

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CSST - Installation

- All six manufacturers of CSST have a design and installation guide (D&I)
- ANSI LC-1-2005 Standard (testing and certification)
- Through years of industry cooperation all six D&I guides are nearly identical

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CSST - Installation

- Code requires striker plates to prevent puncture from drywall or other nails and screws
- CSST as a standard is not rated for underground use, but can be installed underground as long as it is run through a protective sleeve. Only one manufacturer's CSST is rated for underground use.

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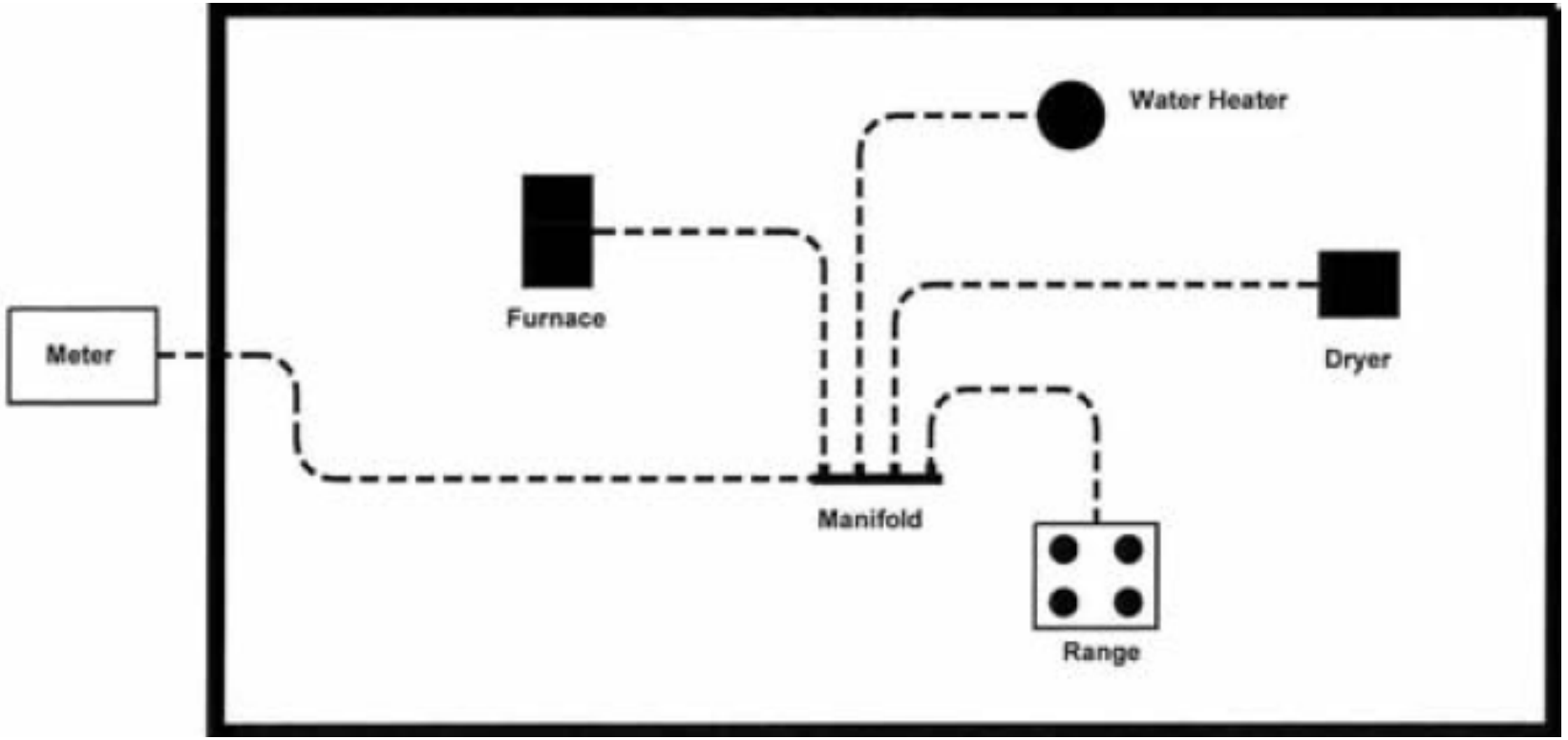
CSST – Diagram



4 Runs without a regulator

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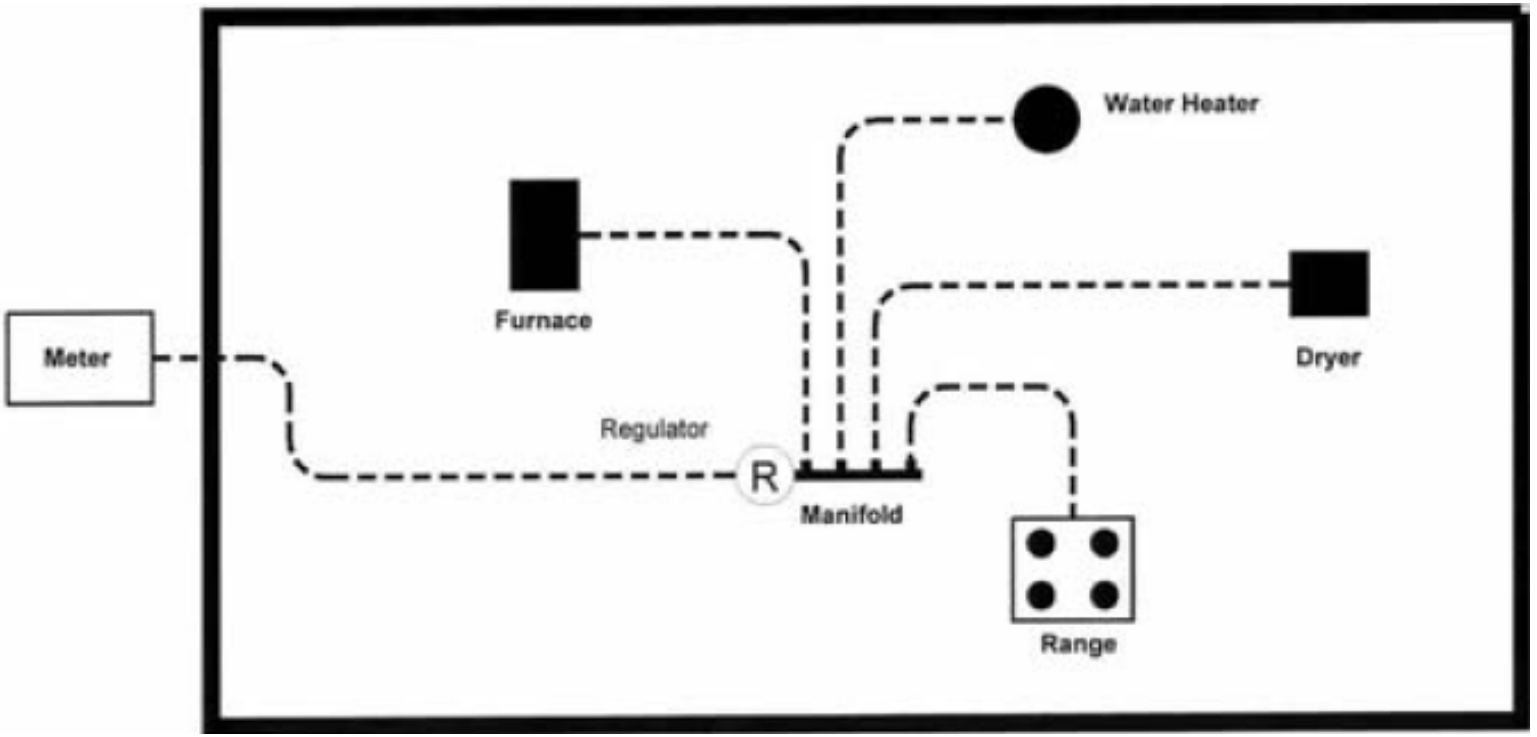
CSST – Diagram



4 Runs with a regulator

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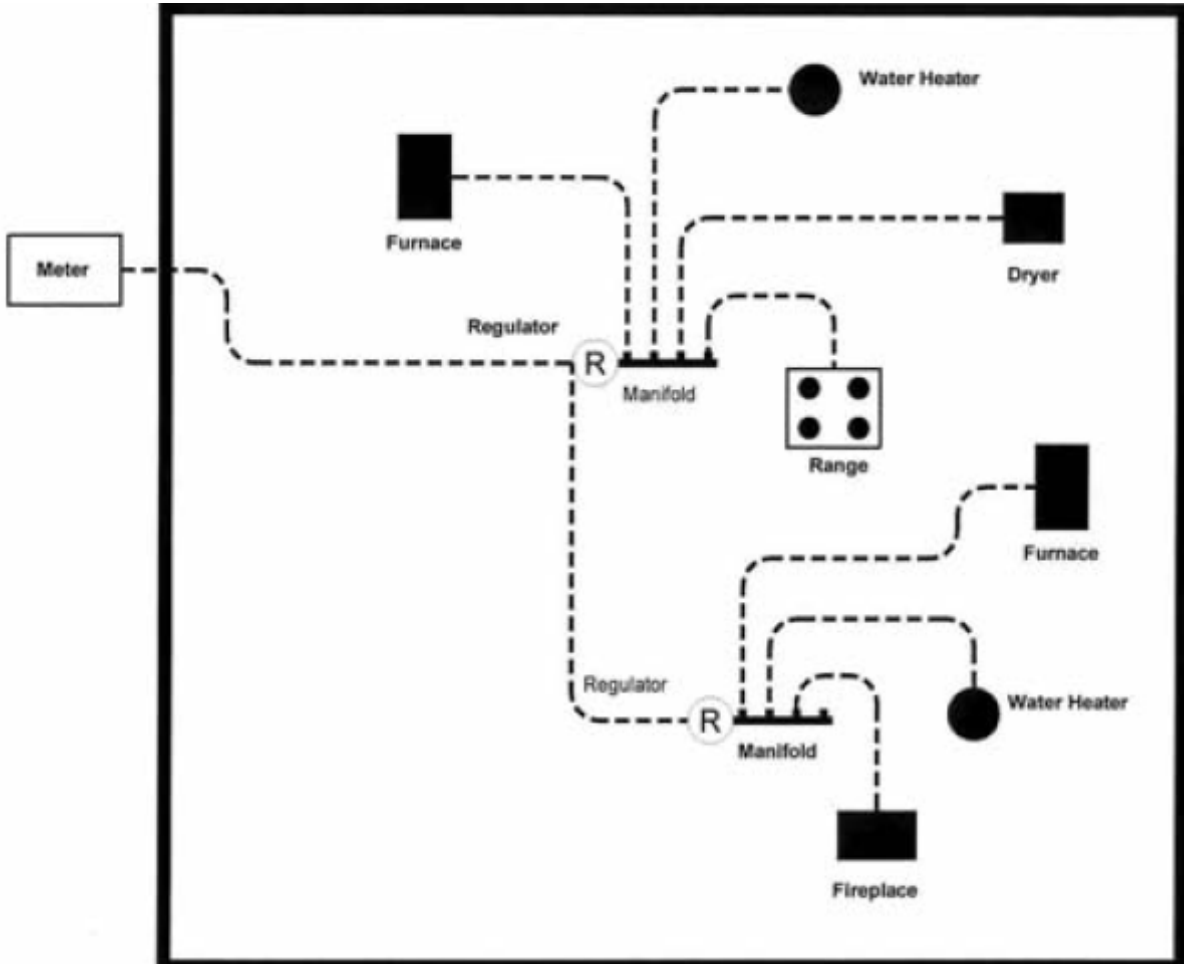
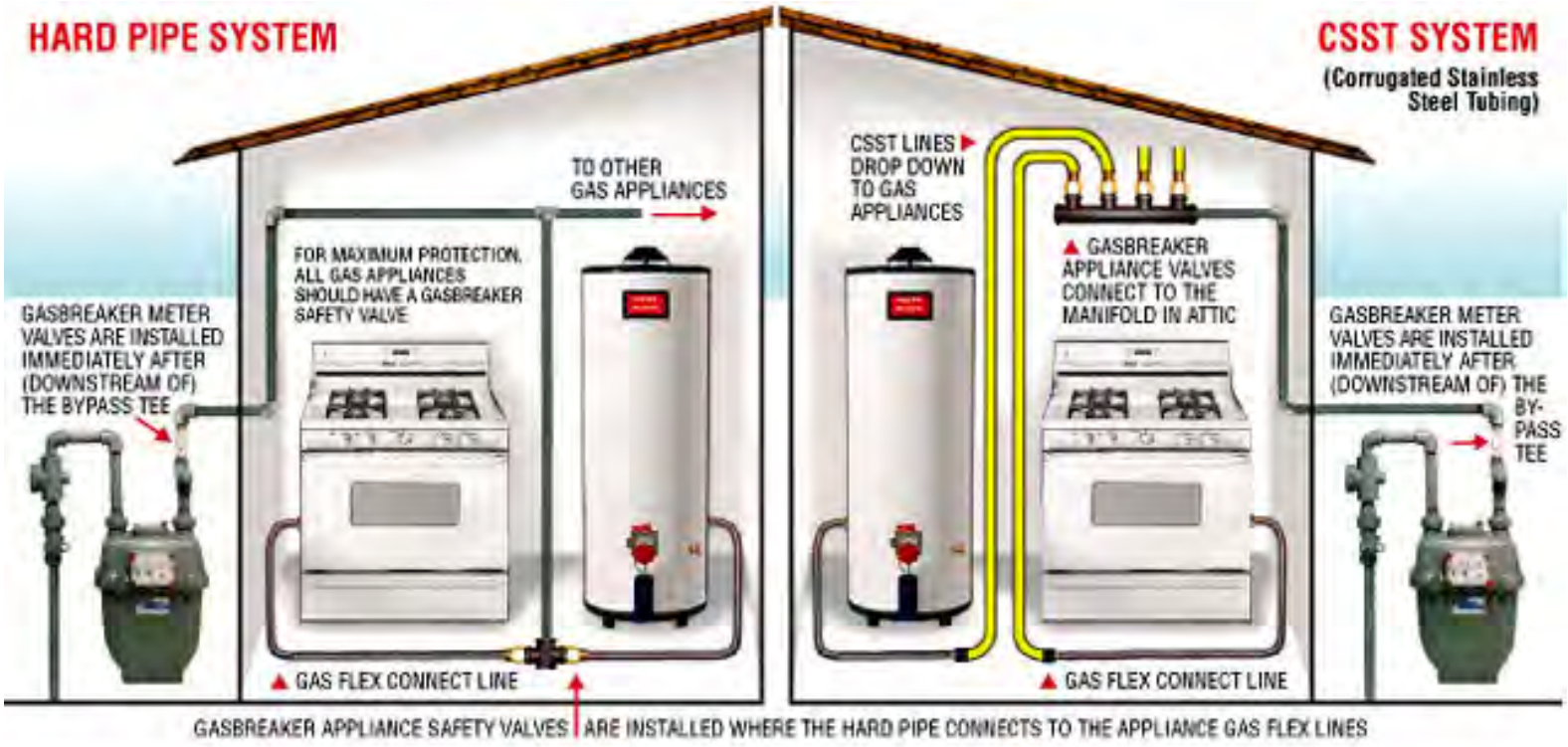
CSST – Diagram



4 Runs with 2 manifolds and **two regulators**

CSST layouts



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CSST - Jacketing

- Bright Yellow Jacket (All Except Omega Counterstrike)
  - Polyethylene jacket is 20 mils thick
- Counterstrike Jacket
  - Black, 100 mils thick

Flash Shield

- Black jacket

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Heat Capacity - Energy

- The following is a table that shows the energy to melt different metals.

Material	Energy
CSST	1
Black Pipe	15
Aluminum	10
Copper	5

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Heat Capacity
Gas Piping

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Material	C (BTU/lbf)	T (F)	H (BTU/lb)	Density (lb/in^3)	Wall thickness (in)	q BTU
CSST (304) 1/2" OD	0.1190	2589.8	128.70	0.285	0.008	0.0078
Black Iron Pipe 1/2" OD	0.1160	2575.4	122.70	0.284	0.109	0.1025
Black Iron Pipe 3/4" OD	0.1160	2575.4	122.70	0.284	0.113	0.1062
Aluminum Tubing 1/2" OD	0.2100	1166.0	167.30	0.098	0.035	0.0111
Copper Tubing 1/2" OD	0.0920	1981.0	88.05	0.323	0.040	0.0274

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Thermal Diffusivity

- Fourier Transform (heat transfer and time) calculations show penetration time
  - CSST (13 mils)– 0.113 seconds
  - CSST (8 mils) – 0.04295 seconds
  - Black Iron (109 mils, schd 40) – 1.47 seconds
  - Black Iron (113 mils, schd 40) – 1.93 seconds

- Cloud to ground lightning discharge lasts on average two hundred microseconds

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Thermal Diffusivity

- Conclusion: the thicker walls of black iron being perforated by arcing will be extremely rare – as in I have never seen one

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Bonding and Grounding

- A World of Confusion

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Bonding and Grounding

- Applicable Codes
  - National Electrical Code
  - National Fuel Gas Code, NFPA 54
  - Lightning code NFPA 780

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Bonding and Grounding

- NFPA 54 vs NEC
  - Both from same ‘Author’ – NFPA
  - Harmony is required

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Grounding

- What is grounding?
  - The dissipation of electrical energy through different techniques

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Grounding

- Gas Systems
  - Needs to be Bonded to Ground
  - Gas Piping is not to be Used as a Ground

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Grounding

- On a residence the ground must be 25 Ohms or a second method of grounding is required

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Grounding - Sizing

- NEC sizes the bonding jumper based on the circuit that is likely to energize the gas piping system.
- Table 250.122: Minimum Size Equipment Grounding Conductors for Grounding Raceways and Equipment

Ampres	Size AWG Copper
15	14
20	12
30/40/60	10
100	8
200	6

- Does not take into account lightning strikes.

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Grounding

- Typical Grounding Methods
  - Ground Rod
  - Ufer
  - Cold Water Ground

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Grounding

- A house is typically grounded near the meter with one or two rods. The rods are copper plated and around 8 feet long. The attaching ground wire is usually #6 AWG.

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Grounding Ground Rod

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Grounding

- Ufer Ground – Ties electrical system to rebar

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Grounding

Ufer Ground

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Grounding

Cold Water Ground

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Grounding

- Cold Water Ground Disadvantages
  - Many water supply lines are now poly (PEX)

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Grounding

- Gas Line Grounding
  - Gas line is not to be used as a ground
  - Per NFPA 54 and NEC – In Harmony

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Grounding

- EXACT TEXT – 1988
  - Each above ground portion of a gas piping system upstream from the equipment shutoff valve shall be electrically continuous and bonded to any grounding electrode as defined in the National Electrical Code, ANSI/NFPA 70.
  - (b) Gas piping shall not be used as a grounding electrode.

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Grounding

- EXACT TEXT – 2002
  - Each above ground portion of a gas piping system that is likely to become energized shall be electrically continuous and bonded to an effective ground-fault current path. Gas piping shall be considered to be bonded when it is connected to gas utilization equipment that is connected to the equipment grounding conductor for the circuit supplying that equipment.
  - (b) Gas piping shall not be used as a grounding conductor or electrode.

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Grounding

- Gas Line is to be Bonded to Ground
  - NFPA 54 and NEC
- This brought confusion

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Bonding

- What is bonding?
  - The permanent joining of metallic parts to form an electrically conductive path that ensures electrical continuity and the capacity to safely conduct any current likely to be imposed.

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Bonding

- Why Bond?
  - To Prevent Explosions
  - To Prevent Electrocutions

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Bonding

- The Correct Name –
  - Equipotential Bonding (Equal Potential)
  - Not Well Understood

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Bonding

- Equipotential Surfaces –
  - Prevent Arcing
  - Protection from Electrical Shock

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Bonding

- The Conundrum –
  - Code interpretation by some officials prevent bonding of gas lines

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Bonding

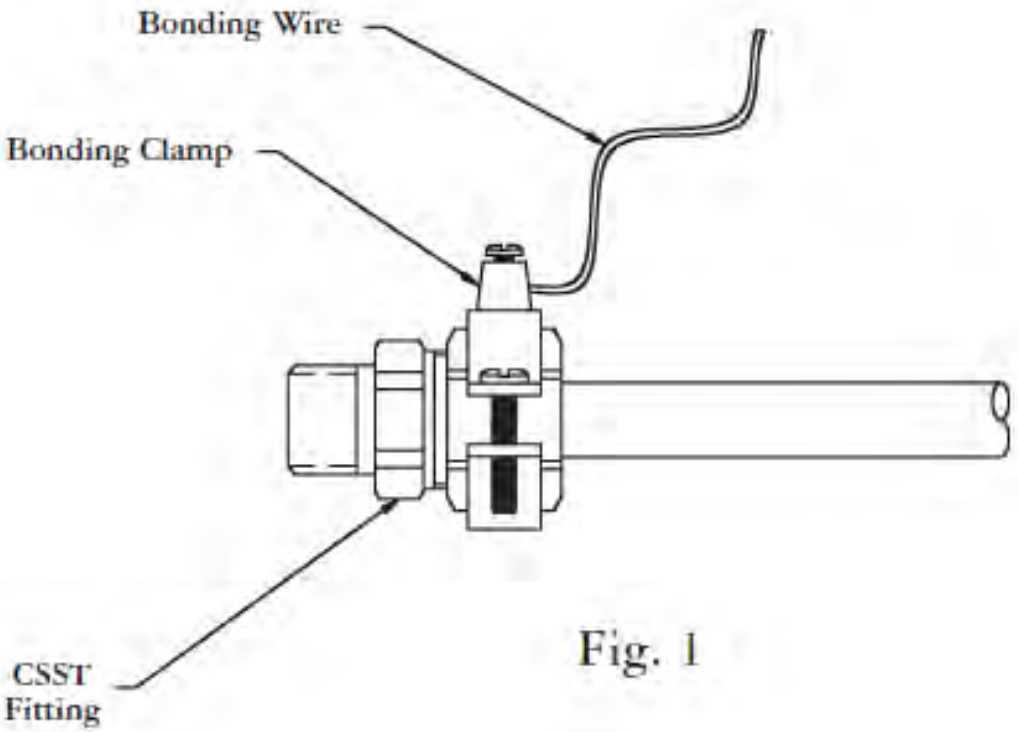

Fig. 1

Bonding wire should not be bent in 90 degree angles. Sharp bends increase inductance. Bending Radii greater than 8 inches.

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Bonding

- When a Gas Line is Bonded to Electrical Ground, Gas Lines Become Part of the Ground

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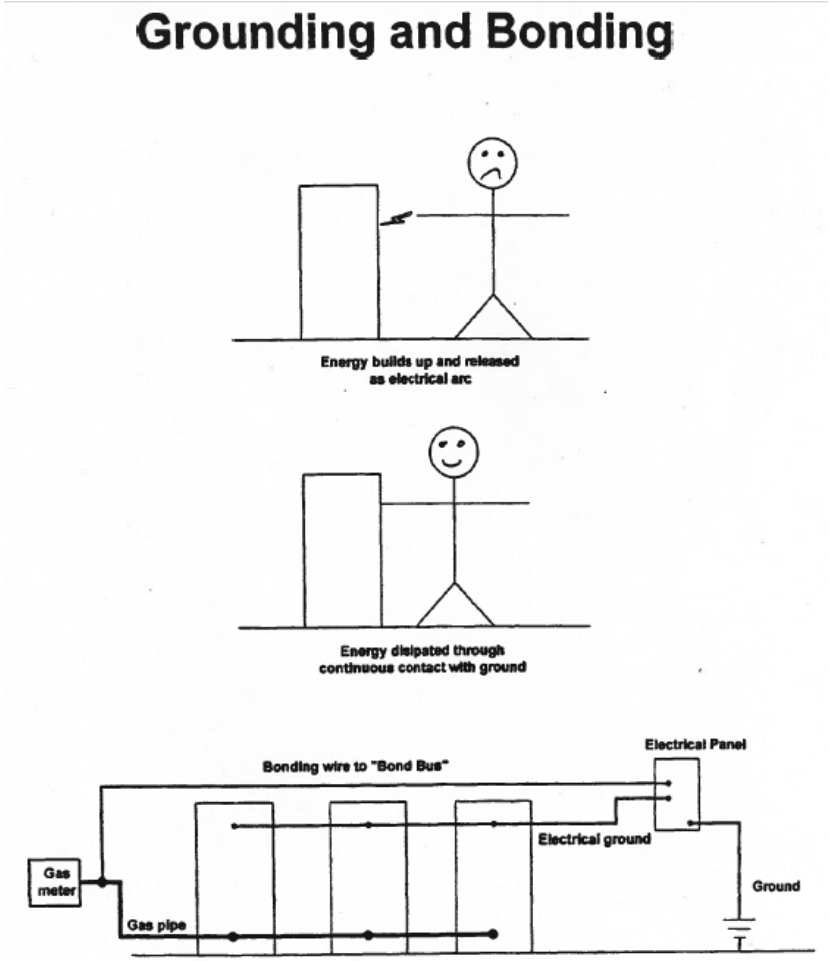
Grounding and Bonding



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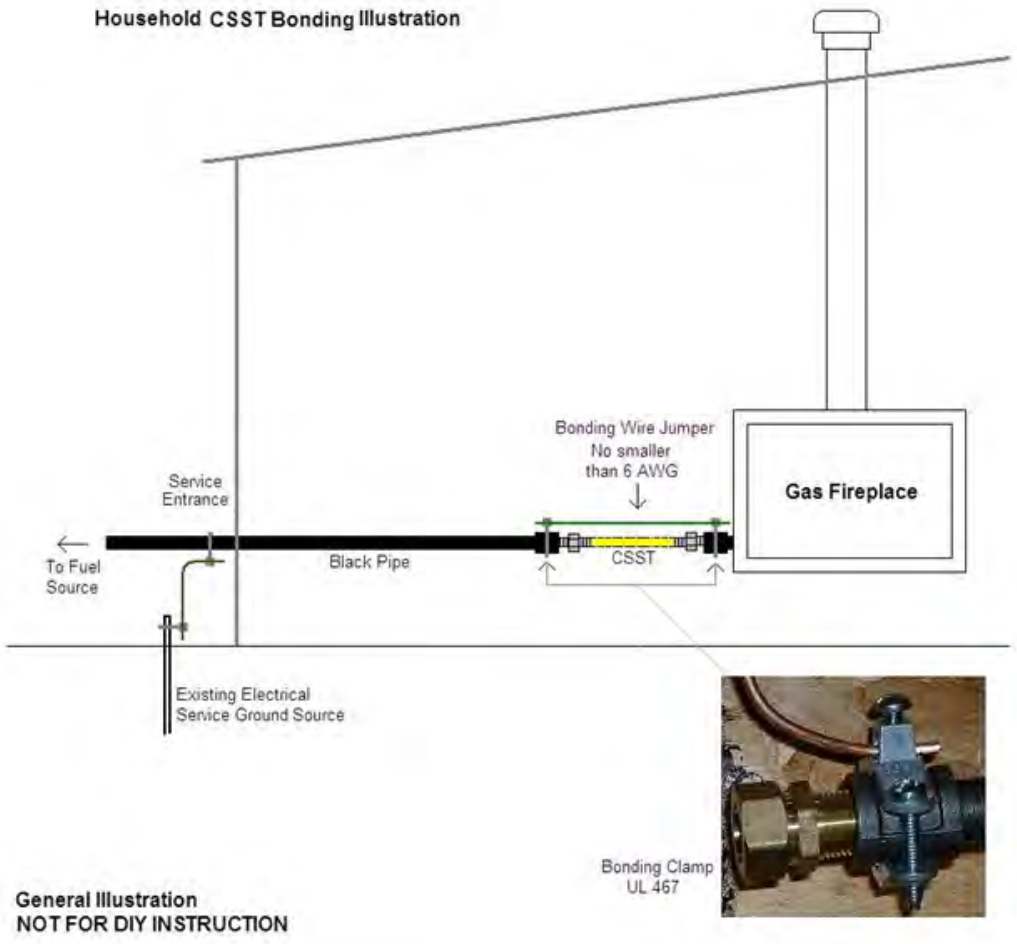
CSST - Bonding



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CSST - Bonding

- There is not an NEC requirement to bond non-electric gas fired appliances.

- There is not an NEC requirement to bond the chimney.

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Bonding

- 1996 NEC
  - Grounding a Grounded Gas Appliance Bonds the Appliance to Ground

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Bonding

- Code Misinterpretations – by Officials
  - Gas piping shall not be used as a grounding conductor or electrode

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Bonding

- Code Misinterpretations – by some experts and NAHB
  - 1999 Code – NEC 104b – Each aboveground portion of a gas piping system upstream from the equipment shutoff valve shall be electrically continuous and bonded to the grounding system.

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Bonding

- 1999 code Wording – Confusing
  - Interpreted by some to require a separate bonding jumper

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Bonding

- NAHB Chart

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

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NAHB - Report

- This report is in Error.

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Bonding

- Where did some go wrong?
  - NEC formal interpretation

- NEC states that when a gas furnace (as an example) is grounded, the gas system is effectively bonded.

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Formal Interpretation

Formal Interpretation

NFPA 54
National Fuel Gas Code
1999 Edition

Reference: 3.14 (a)
F.I. No.: 54-99-1

"Each aboveground portion of a gas piping system upstream of the equipment shutoff valve shall be electrically continuous and bonded to the grounding electrode system."

Question: Is it the intent of NFPA 54, 3.14(a) and NEC 250-104(b) (metal gas piping), to consider this bonding requirement to be satisfied where a grounded gas appliance is attached to the metal gas piping system?

Answer: Yes.

Issue Edition: 1999
Reference: 3.14(a)
Issue Date: April 7, 2000
Effective Date: April 27, 2000

Bonding

- What about a gas fireplace?
- What about a gas water heater?

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Bonding

- If the appliance does not use electricity, there is (per the NEC) No reason to Bond.

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Bonding

- Typical Bonded Gas Appliances
  - Gas Stove w/ Electric Start
  - Gas Furnace w/ Electric Blower
  - Gas Furnace w/ Grounded Outdoor AC Condenser

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Bonding

- Fallacies of Bonding?

- Ignores Current Levels
- Trying to apply 60 Hz Theory to Lightning, It is Different
- Equipotential is wrong

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Bonding

- Fallacy #1
  - Assume a 1 ½ HP 120 volt motor
  - Current – 16 amps on 120 VAC circuit
  - Brand Circuit 12/2 with ground

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Bonding

- Maximum Fault Current is Limited by
- 12 AWG Wire

- Ergo, 12 AWG Ground Wire is Sufficient

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Bonding

- BUT!
- With Lightning, Fault Current can be 1000's of amperes
- 12 AWG will fail

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Bonding

- Bonding and Grounding do not take into account that fault current is limited

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Bonding

- Fallacy #2
  - Equipotential Surfaces – Apply only to DC,
  - 60 Hz
  - Equipotential Surfaces Virtually Non Existant at Lightning Frequencies (Risetime Issue)

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Bonding

- Voltage Drop Across Inductive Circuit

- $V = L \, di/dT$

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7-13.2 CSST

- CSST gas piping systems shall be bonded to the electrical service grounding electrode system at the point where the gas serviced enters the building. The bonding jumper shall not be smaller than 6 AWG copper wire or equivalent

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Bonding and Grounding

- Does it really matter?

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Who is Responsible?

- Whose job is it to ground and bond CSST?
- Plumber?
  - He / she can't do electrical work?
- Electrician?
  - May not even know CSST is present
- General contractor?
  - May not know CSST is being used
  - GC us usually after code compliant plumbing and electric –
  - Fixtures spec'd, not wire or pipe types

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- How about?
  - Plumber tells electrician
  - Electrician then bonds CSST
- But….
- Electrician is obligated to follow NEC
- NEC does NOT address CSST specifically
- NFGC (NFPA 54) addresses CSST
- Electricians not familiar with NFPA 54
- Electricians don’t carry 54 on their trucks

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Lightning Protection

- Only provided for direct lightning strikes, and that still isn't a guarantee
- Does little to protect structure, electrical, and plumbing from indirect lightning

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Lightning Protection

- Beyond scope and not required per NEC code
- Only certain jurisdictions require lightning protection

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Lightning Protection

- In reality, there are no construction methods or safety measures that can completely protect a structure from a direct lightning strike.

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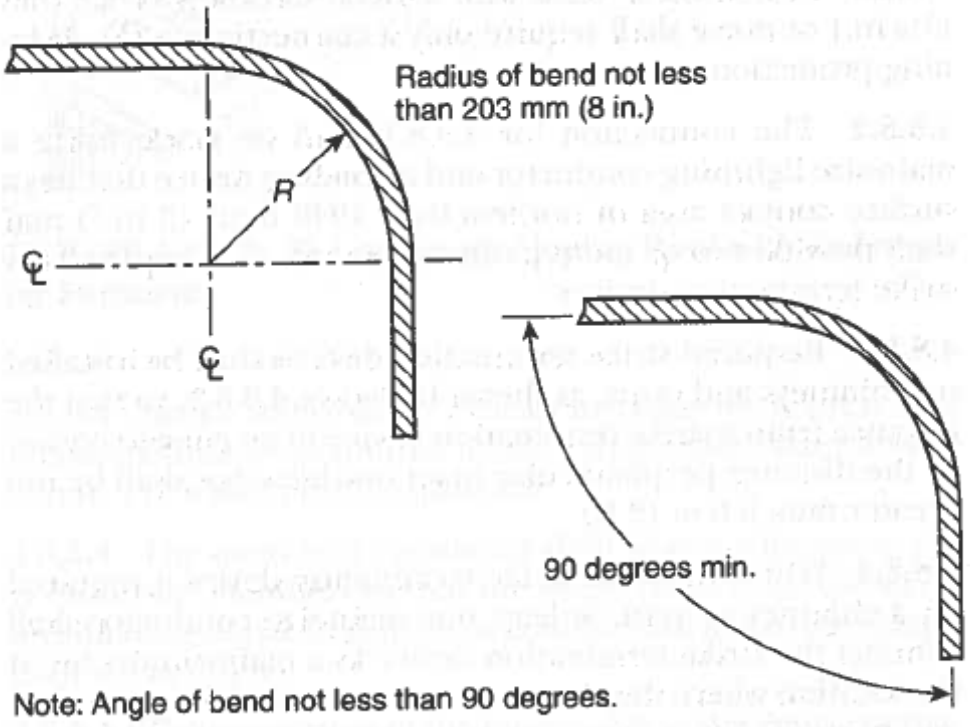
Lightning Rod Cables



NFPA 780 Figure 4.9.5

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Lightning Rod Cables

- NFPA 4.9.5
  - Conductor Bends. No bend of a conductor shall form an included angle of less than 90 degrees, nor shall it have a radius of bend less than 203mm (8 in.), as shown in Figure 4.9.5.

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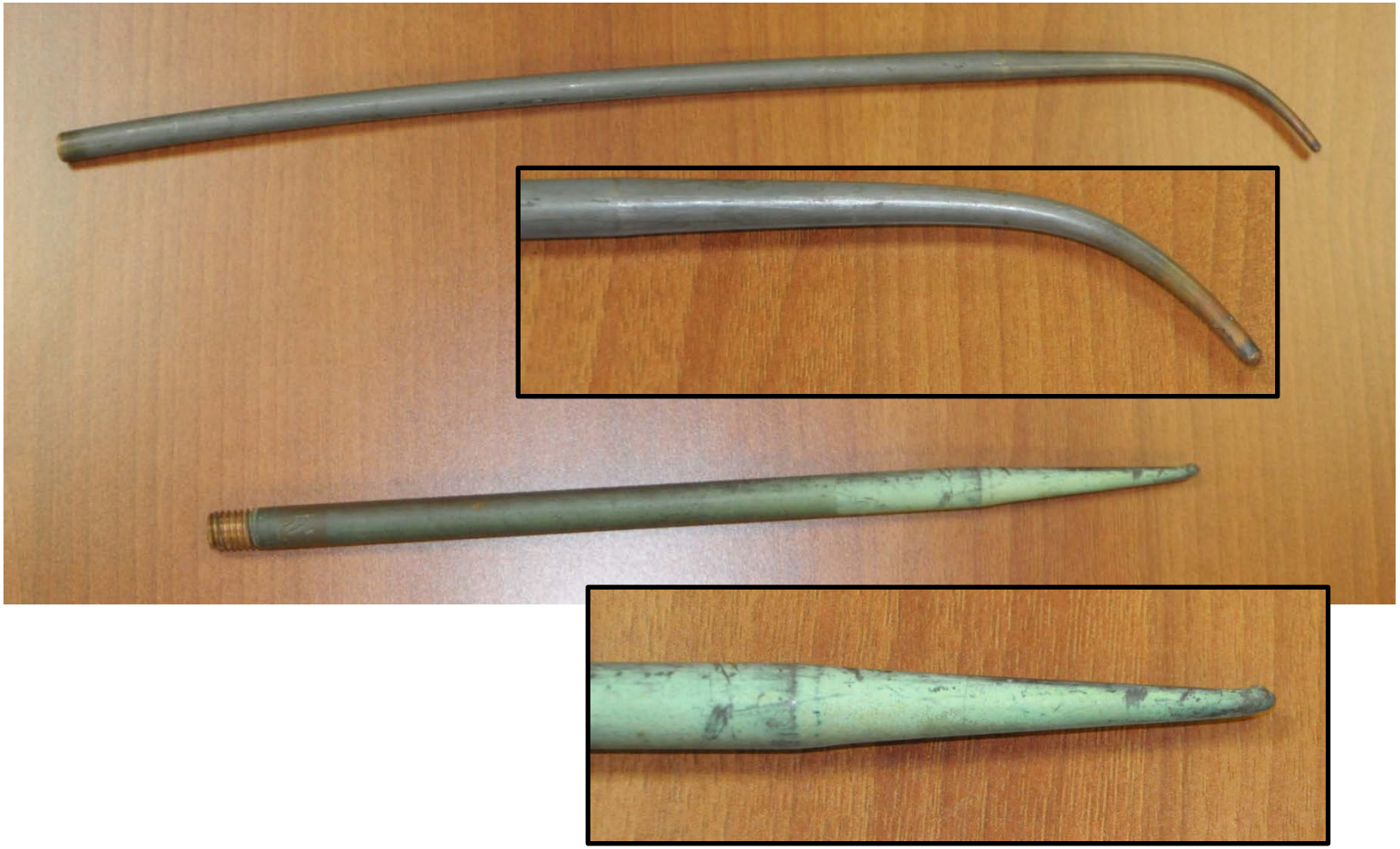
Lightning Rods



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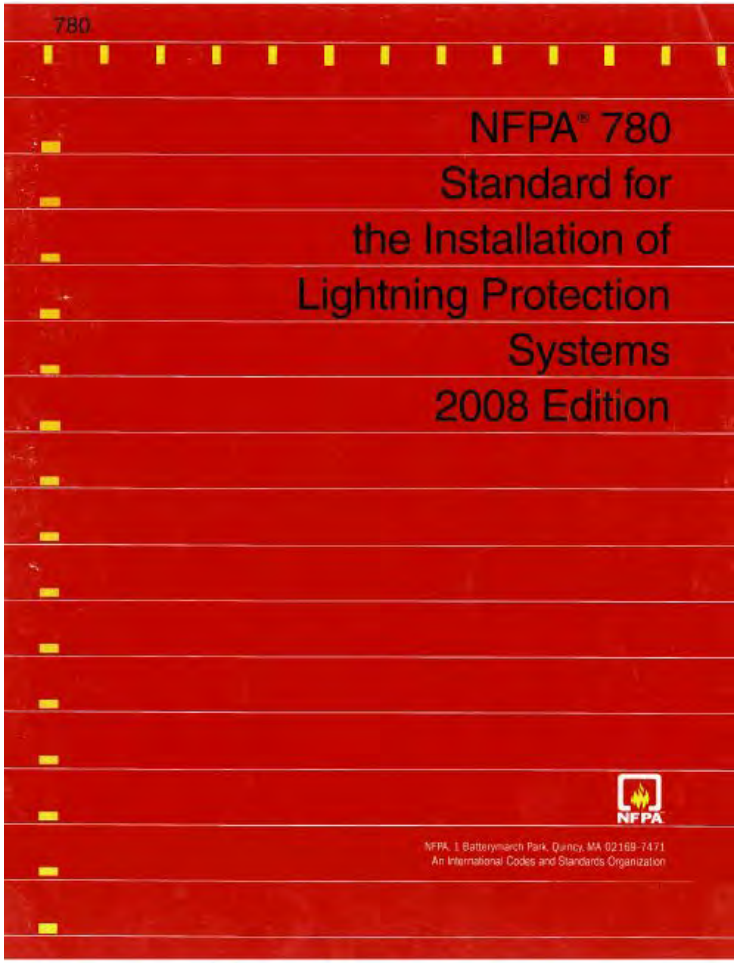
NFPA 780



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CSST Testing Protocols

- Examine the CSST piping runs, documenting the dimensions and identifying any holes in the CSST piping.
- Perform leak testing on CSST piping runs, isolating any further leaks or breaches in the piping. Record capacity flow rates using propane as the test gas and record flow measurements.
- Remove piping runs from the flow test setup and individually examine the holes under stereoscope and photo document any areas of interest.
- Return individual piping runs to the flow testing setup. This time isolate all holes except one. Introduce propane into piping run and attempt to ignite the leaking propane. Document results and cut off propane to piping. Repeat testing again for other breaches or holes in piping testing ignition of propane from holes individually then all at once. Document results.

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CSST Testing Protocols

- Section a portion of the CSST piping where holes were identified. Use a sectioning saw or pipe cutter tool to perform sectioning.
- Inspect areas of interest under a scanning electron microscope (SEM) and perform compositional analysis using energy dispersive xrays (EDX) techniques.
- Remove section of pipe from SEM and ultrasonically clean in a mild detergent or water (Alconox). Repeat SEM and EDS examination on areas of interest.

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CSST Lab Exam Protocols

- **CSST Lab Exam**
-
- Case # :_____ Personnel: MG ST MS LG JJ
- Other _____
- Date: _____
-
-
- Examine all CSST for leaks, visually and / or with air
- Record leakage rate for each breach
- Measure the size (micrometer or optical scope) of each hole
- Using instrumentation, record leakage rate of leak
- Record length of each run of CSST
- Comment on any damage at ends of CSST at fittings
- Apply NG/propane to each run with leaks, measure pressure &
- flame height
- Section each piece of CSST with leakage
- Microscopy of all holes
- Clean, as needed, and re-scope
- Perform real time x-ray of each hole
- Perform SEM / EDAX for each hole
- Measure wall thickness of CSST
- Measure pressure from regulator, if possible

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Lab Tools

- FTIR

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Theory of FTIR

- Fourier Transform Infrared Spectroscopy
  - Identifies compounds and investigates sample compositions
  - Infrared spectroscopy exploits the fact that molecules absorb specific frequencies that are characteristic of their structure.

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Lab Tools

- Cleaning and Polishing

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Theory of Cleaning and Polishing

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- Cleaning allows the sample to have debris such as carbon removed to allow better viewing of sample
- Polishing creates a clean molecular structure for better viewing underneath a microscope

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Lab Tools

- Stereoscope – Leica Microscope

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Theory of Stereoscopy

- Allows magnification and focusing based upon depth. Also allows multiple depth focusing in one picture (montage).

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CSST - Perforation

Stereoscope view

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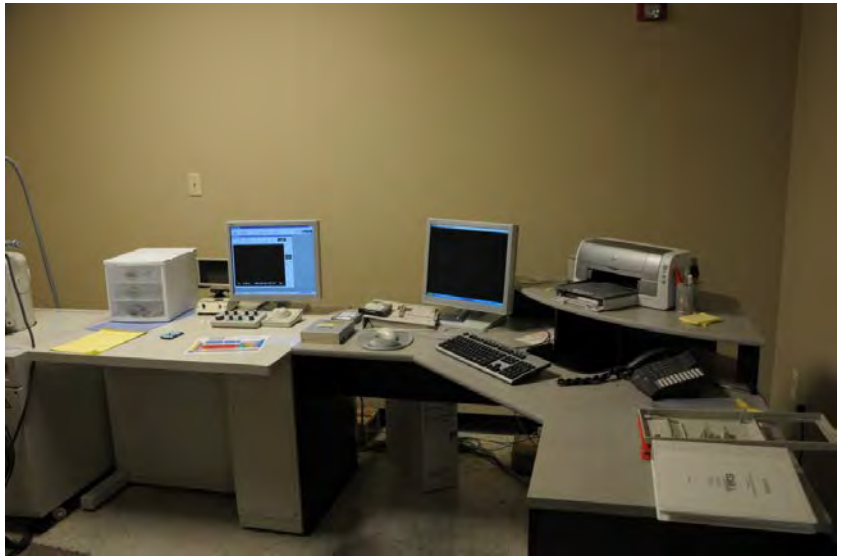
Lab Tools

- Scanning Electron Microscope (SEM)



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Theory of SEM

- Scanning electron microscope
  - Images the sample surface by scanning it with a high-energy beam of electrons. The electrons interact with the atoms to make up the sample's surface topography

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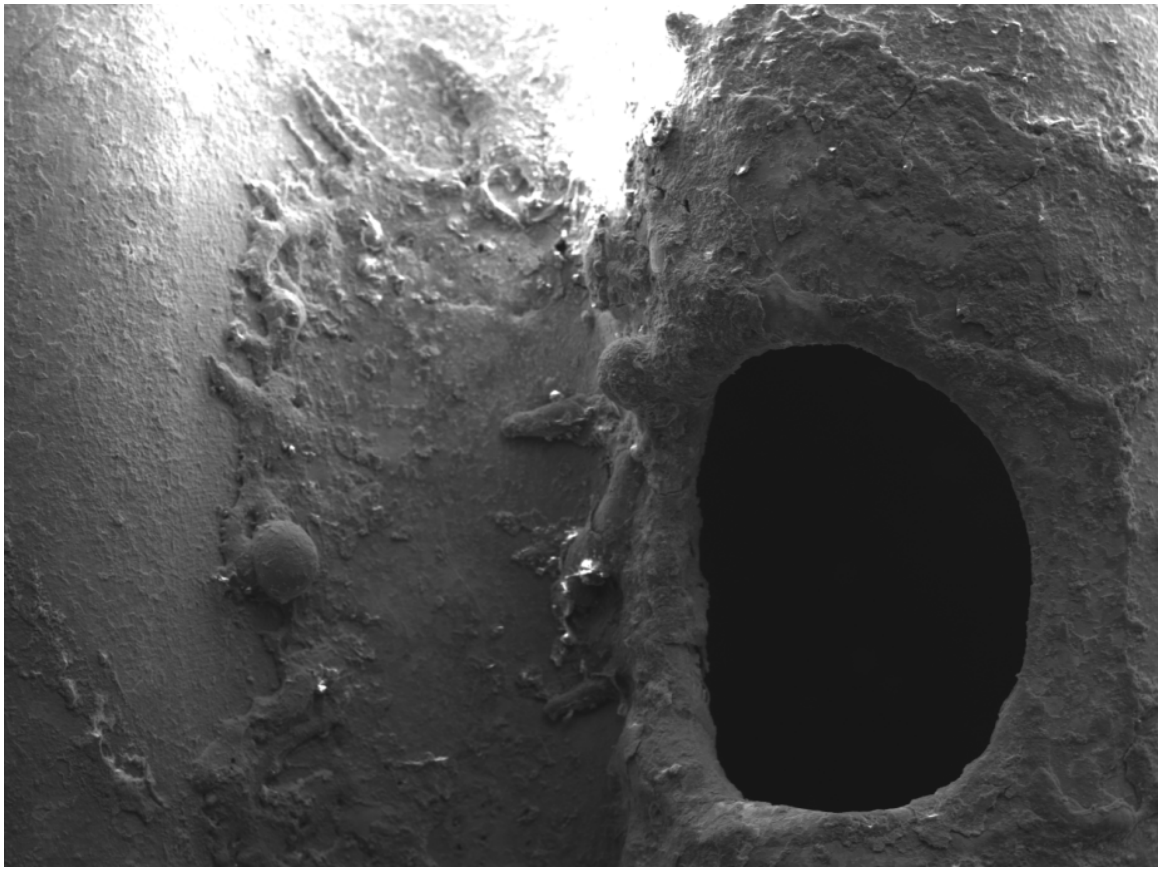

CSST - Perforation

SEM View

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Theory of EDX Analysis

- EDX – Energy Dispersive X-Ray Spectroscopy
  - This is a chemical microanalysis technique used in conjunction with scanning electron microscopy (SEM)

- In English please?
  - The EDX detects x-rays emitted from the sample during bombardment by an electron beam to characterize the elemental composition of the analyzed volume.

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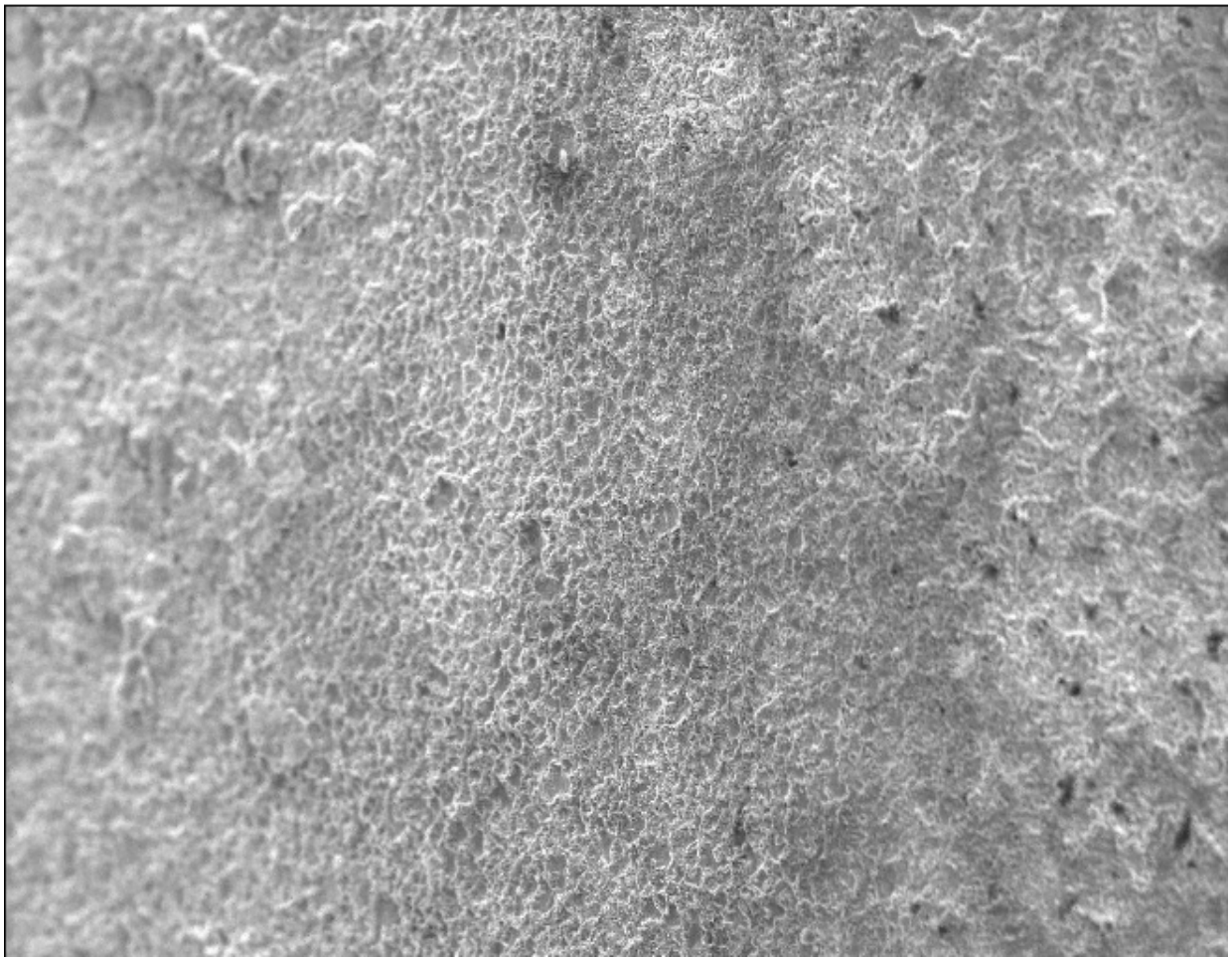
EDX – CSST Base Metal



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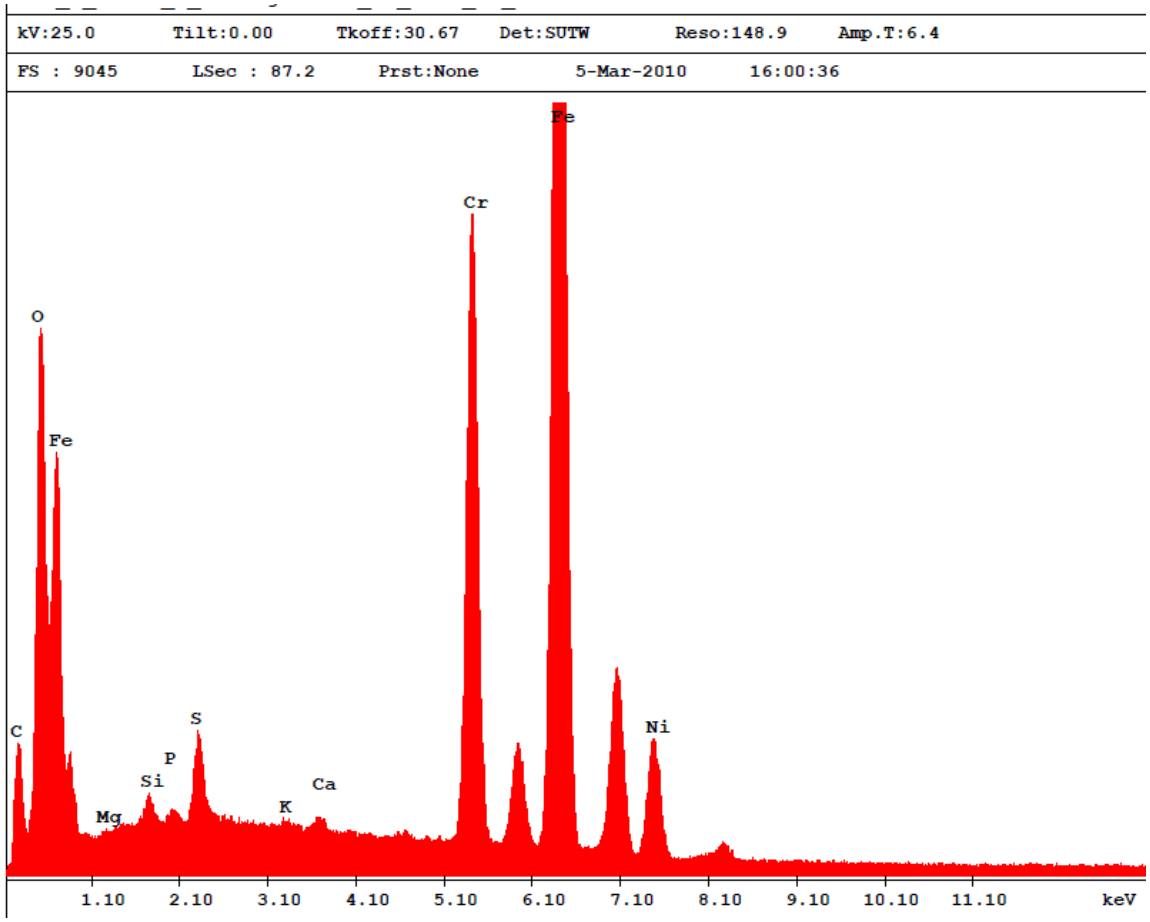
EDX – CSST Base Metal



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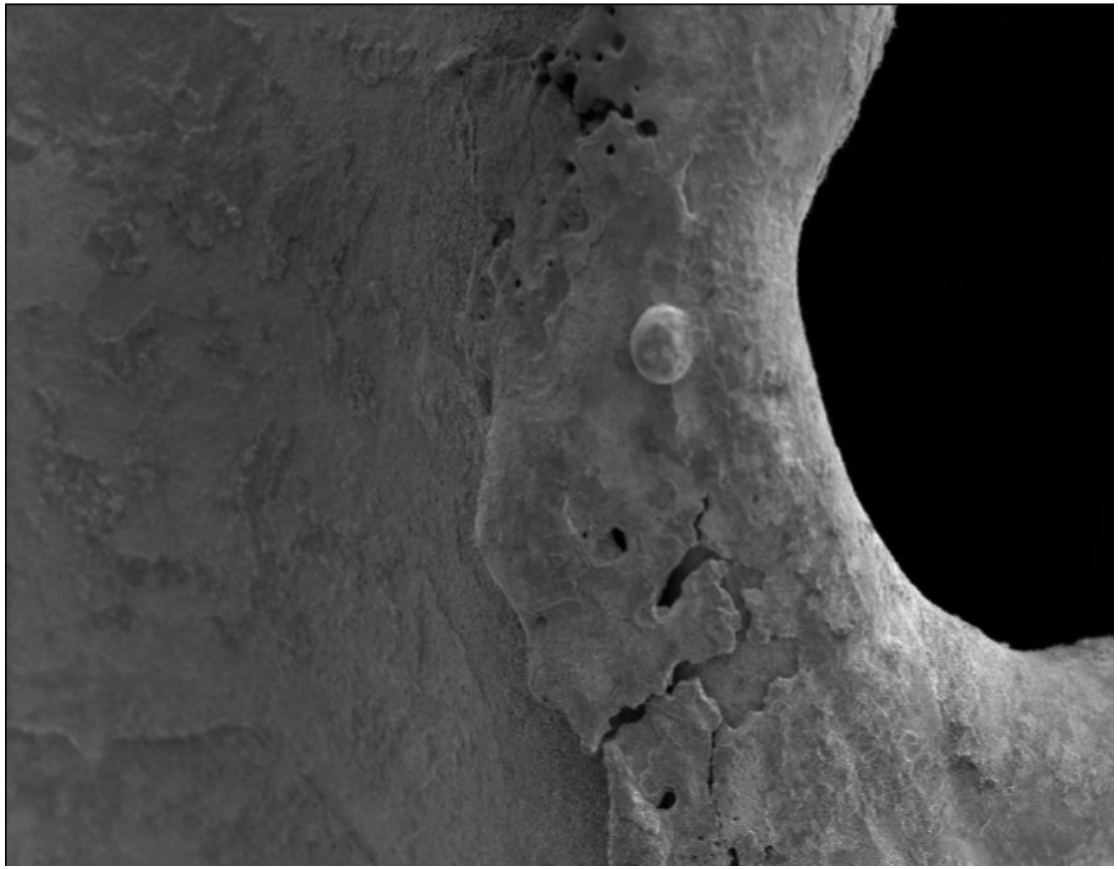
EDX – CSST Hole w/o Copper



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EDX – CSST Hole w/o Copper

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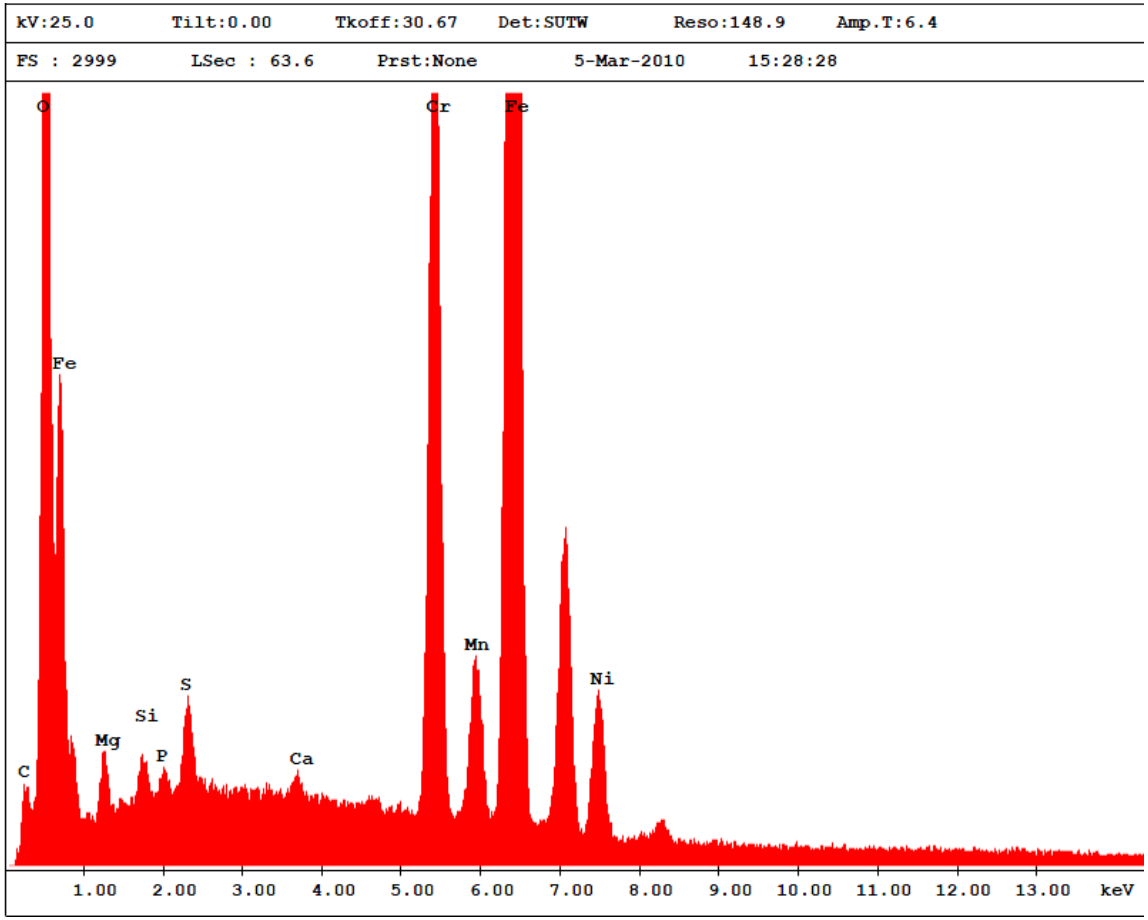

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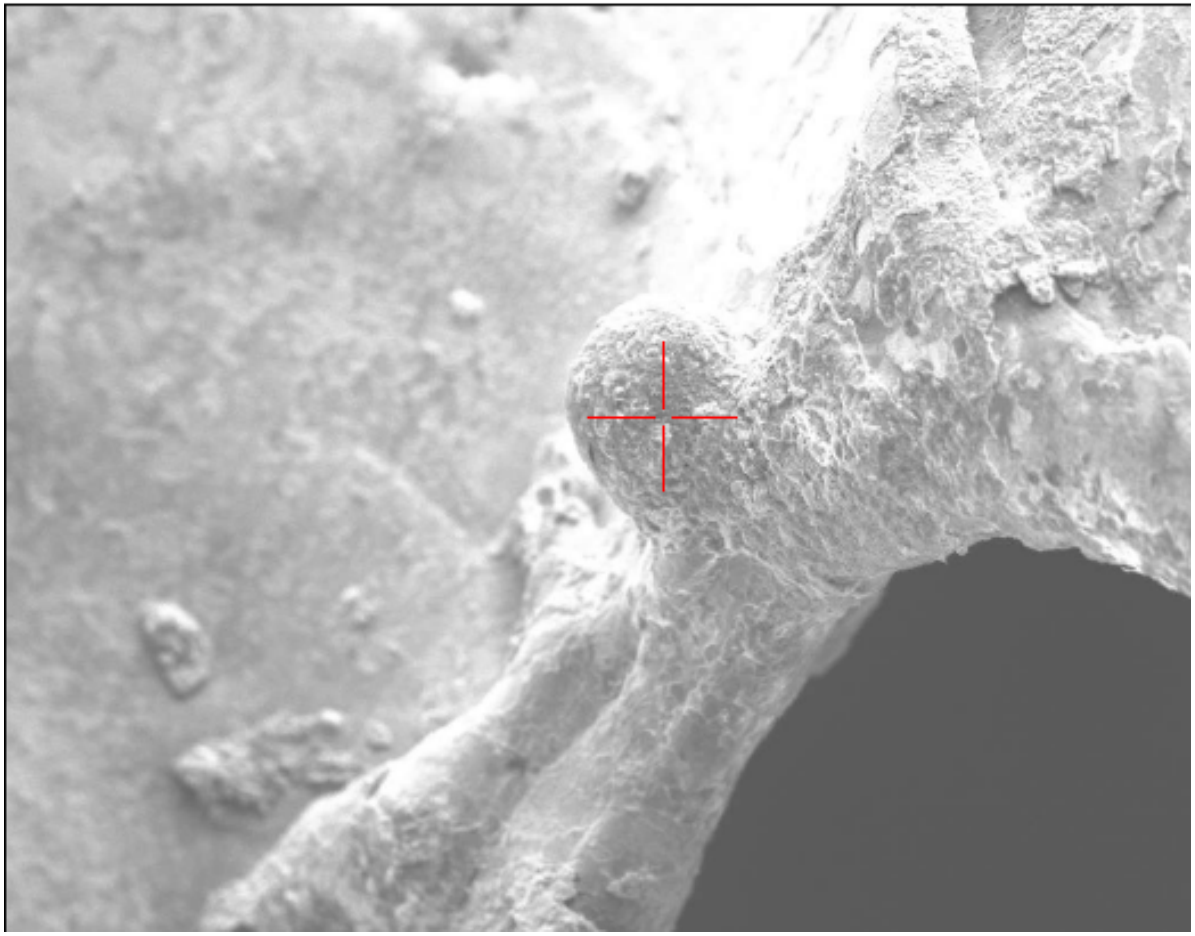
EDX – CSST Hole w Copper



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EDX – CSST Hole w Copper

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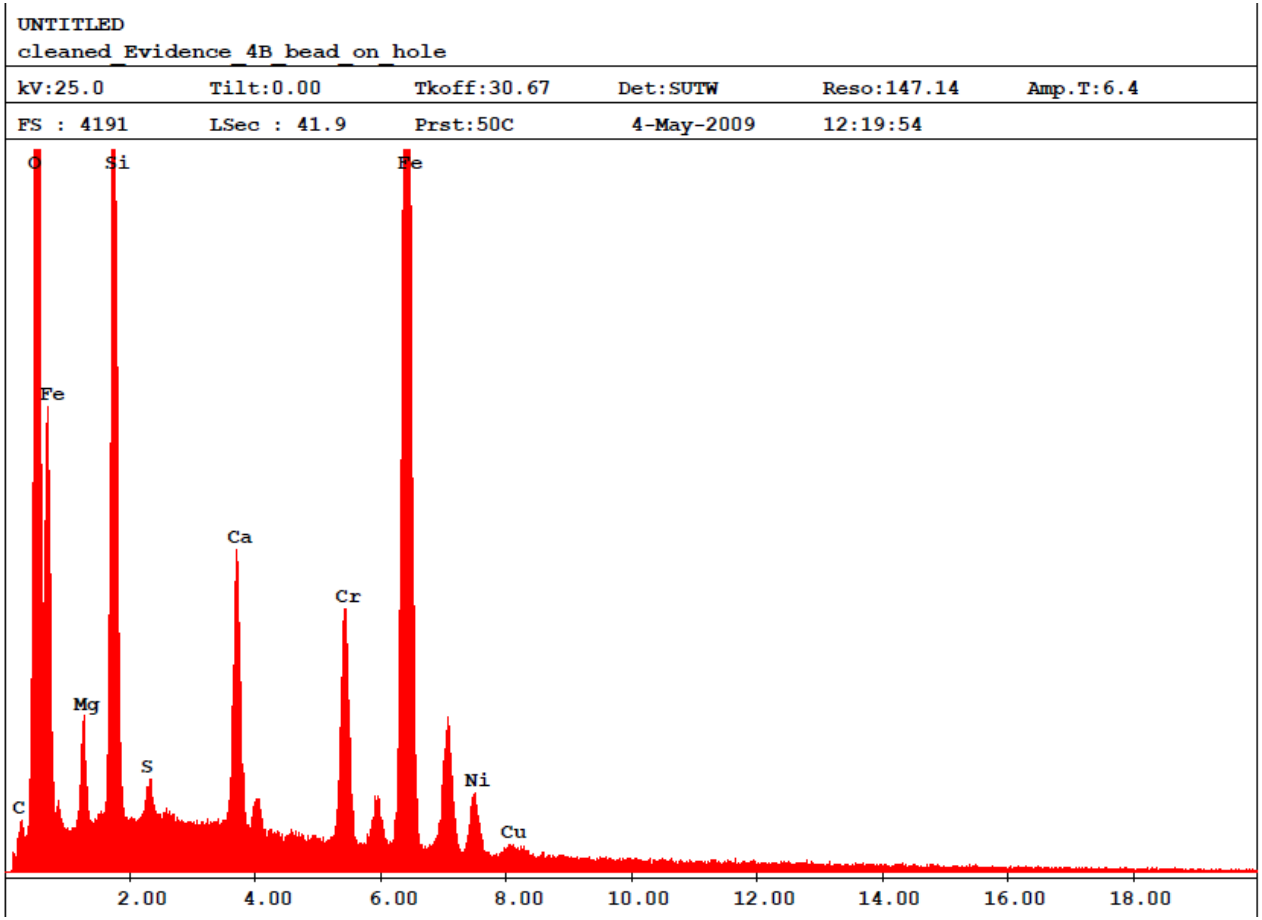

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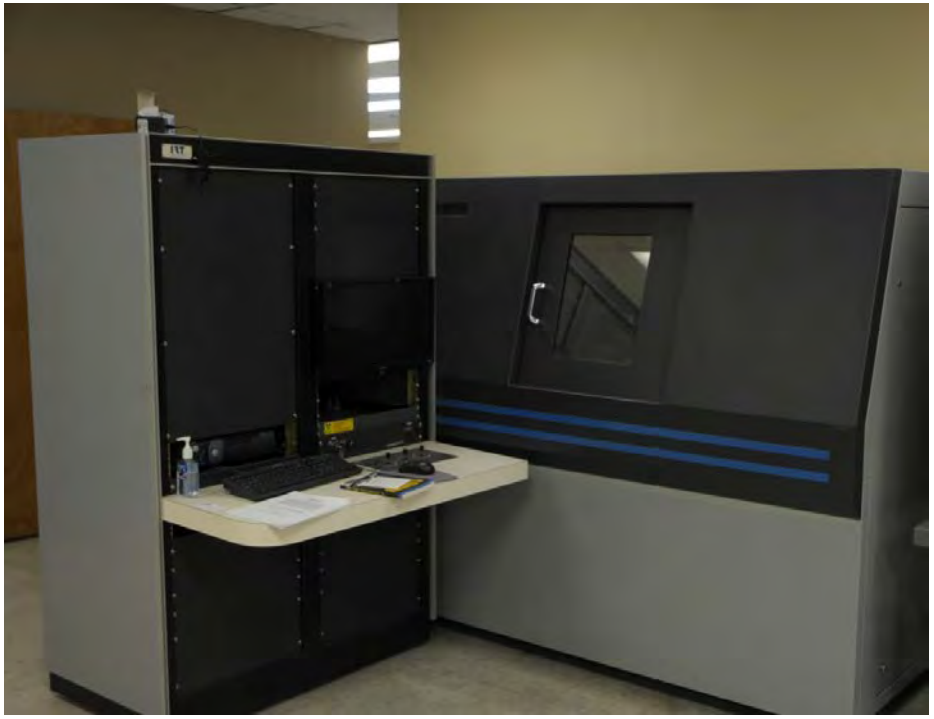
Lab Tools

- Realtime X-Ray



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Theory of X-ray

- Electrons are emitted from a cathode and accelerated to speeds close to the speed of light. The electrons are then focused by a magnetic lens to a very small spot on a metallic target. This produces the images.

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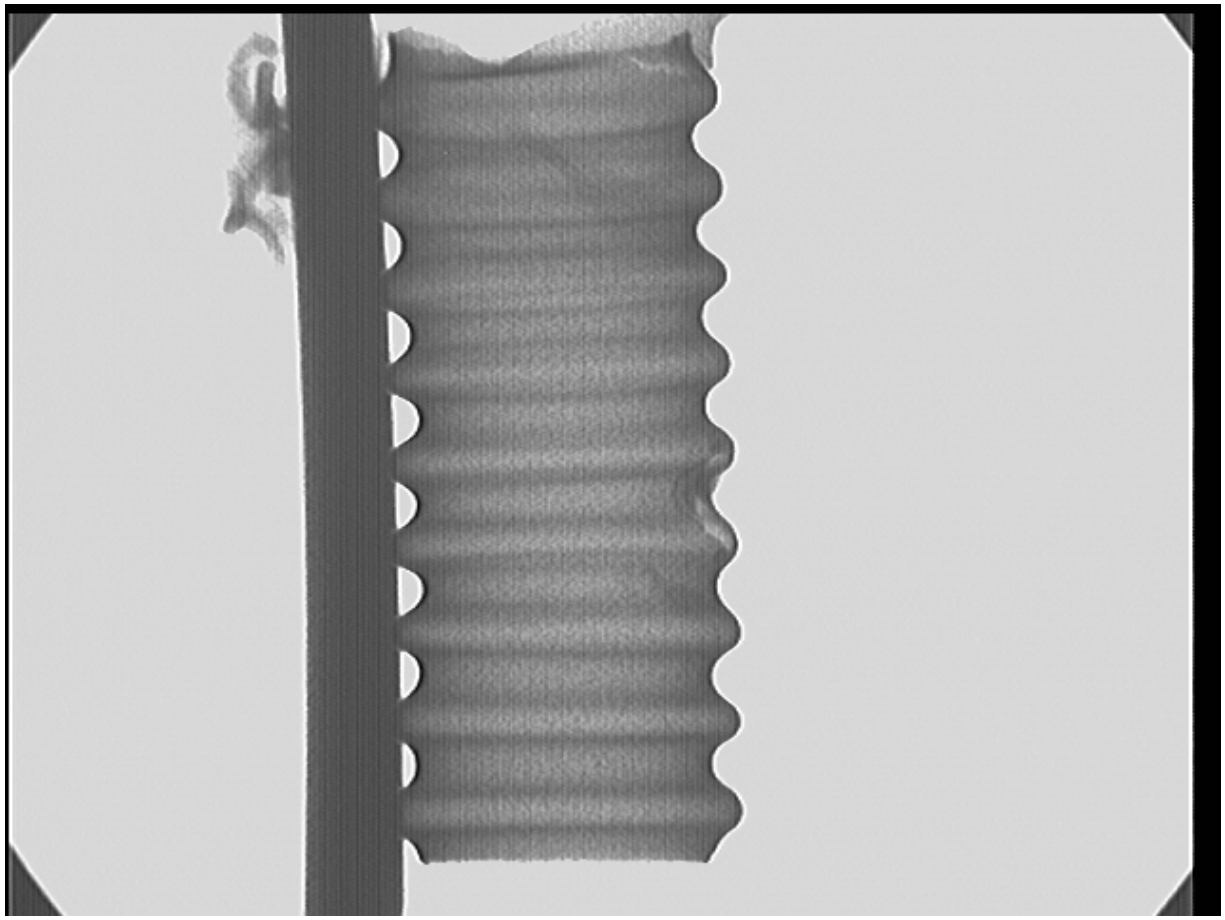
CSST – X-Ray



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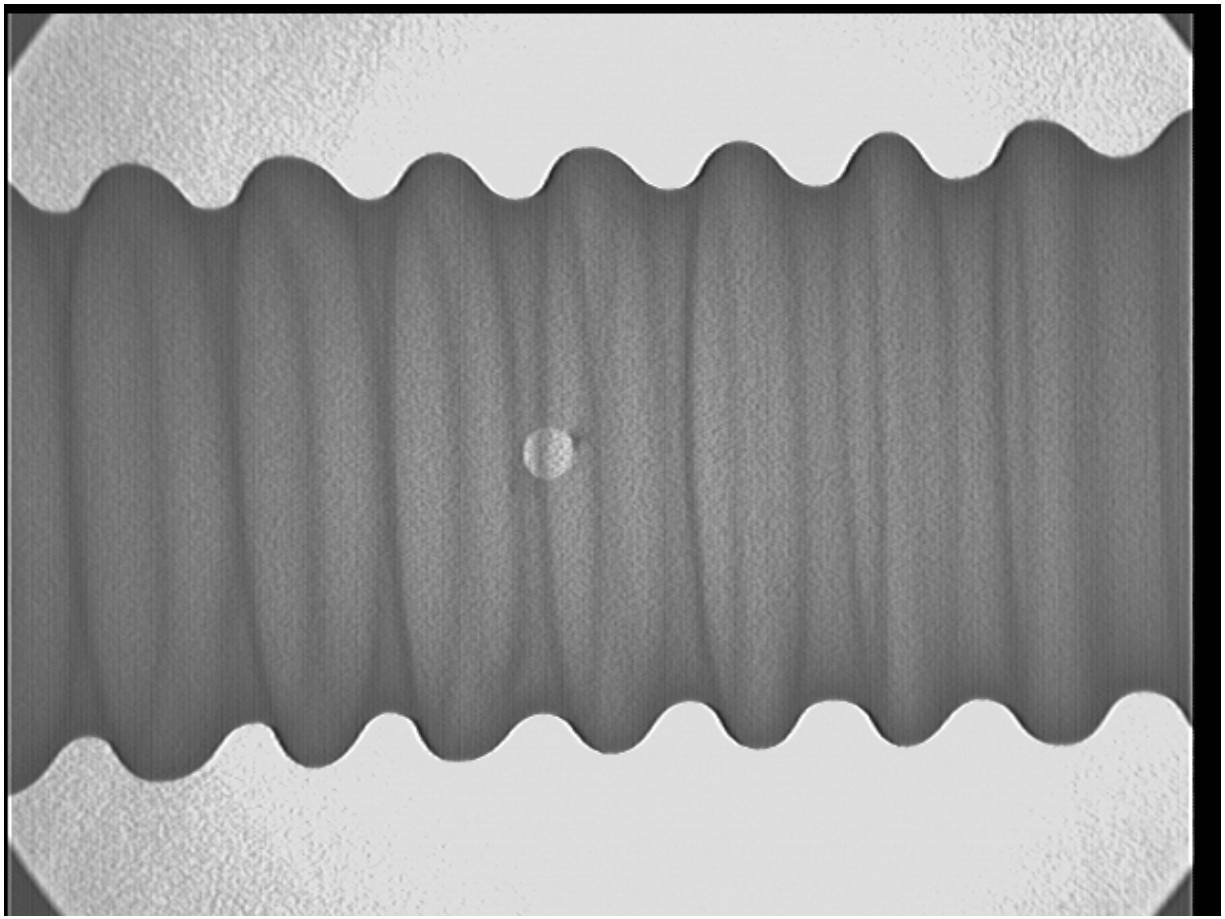
CSST – X-Ray w Drilled Hole



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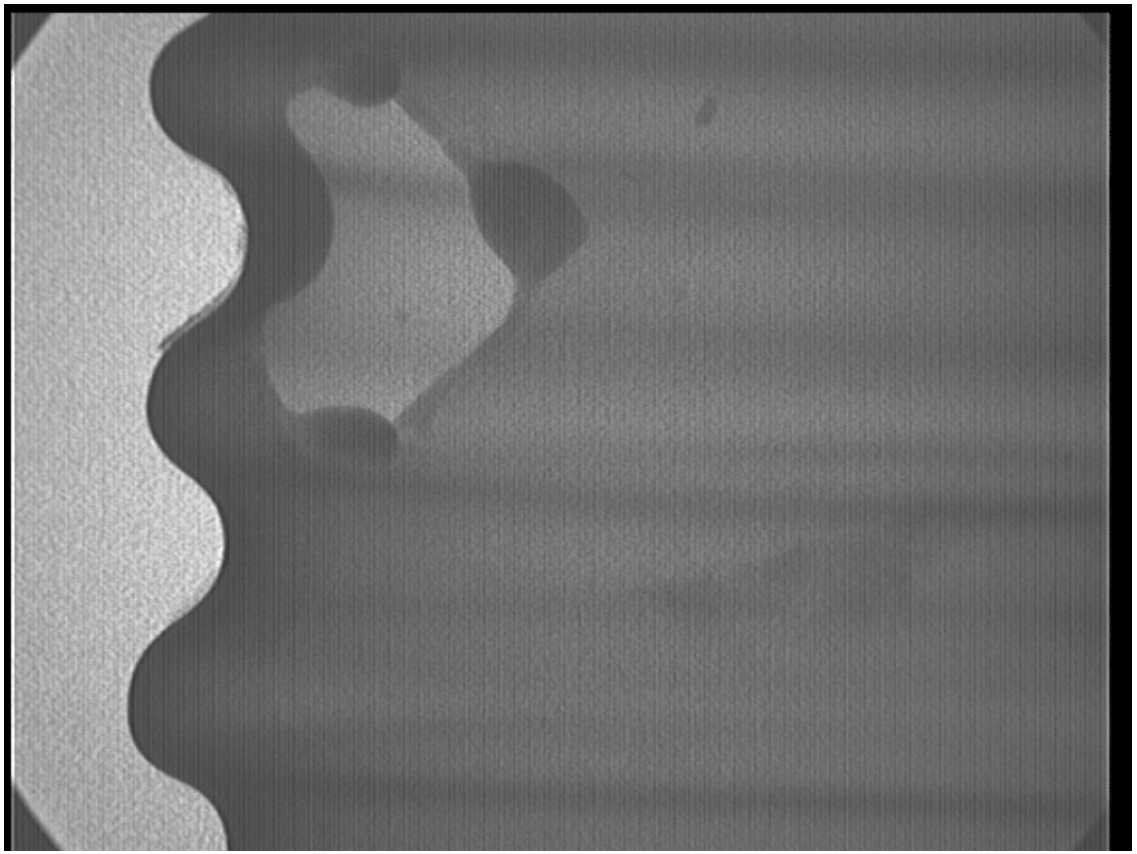
CSST – X–Ray w Spatter



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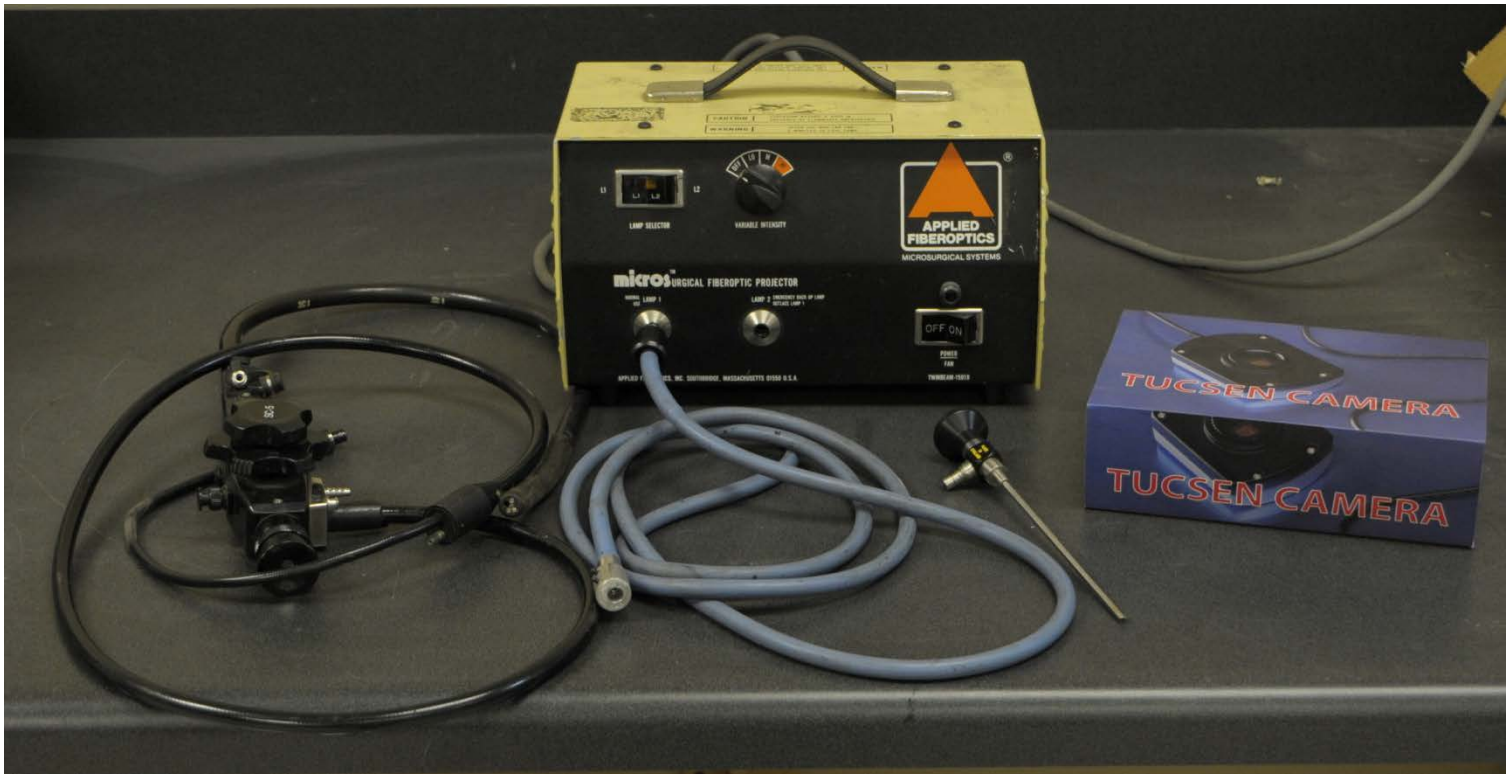
Lab Tools

- Borescope



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Borescope - Theory

- Borescopes allow users to look inside small, deep or complex parts and assemblies without the need for costly and time-consuming tear down or other destructive testing.

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Borescope - Parts

- A borescope uses a combination of lenses, an eyepiece at one end, and some form of tube that can be inserted into tight spaces.

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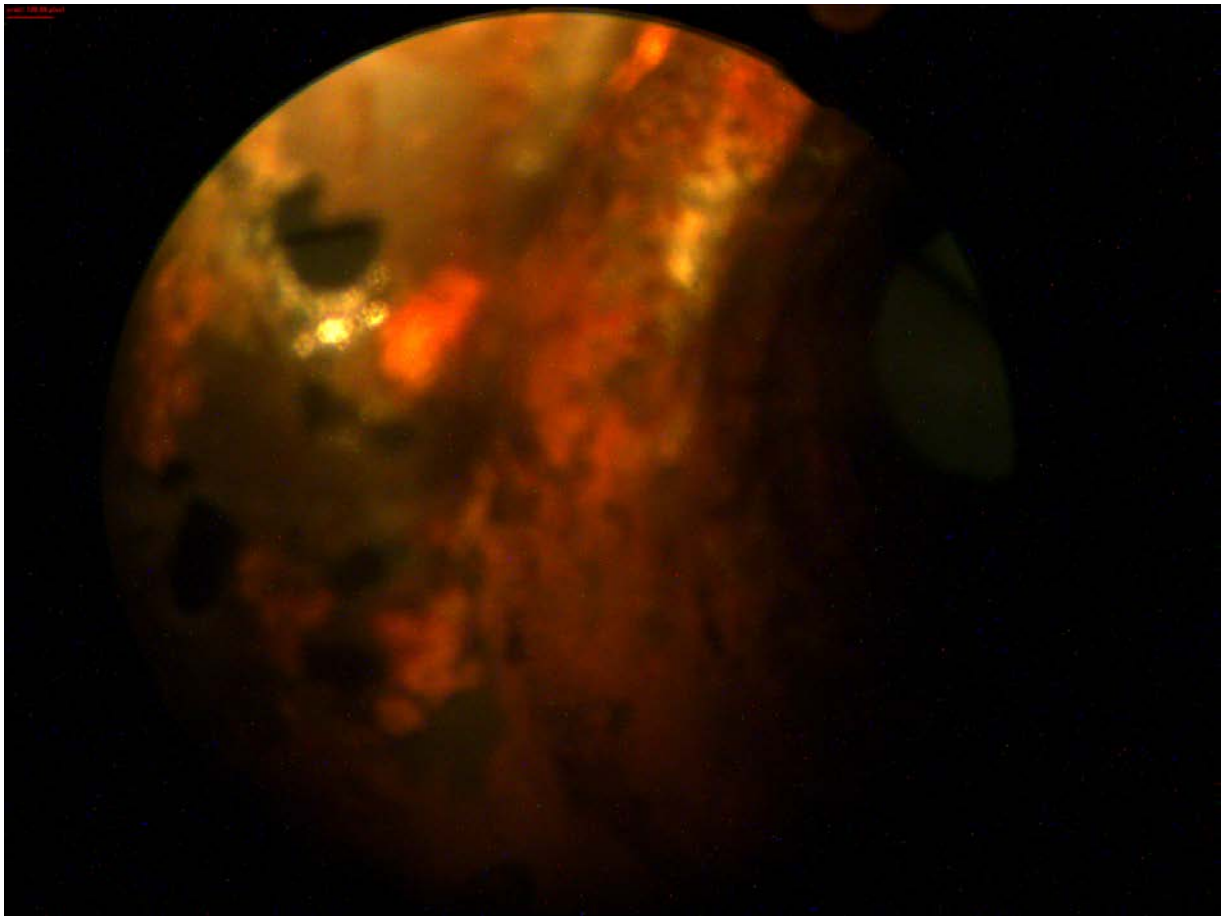
CSST – Interior Borescope



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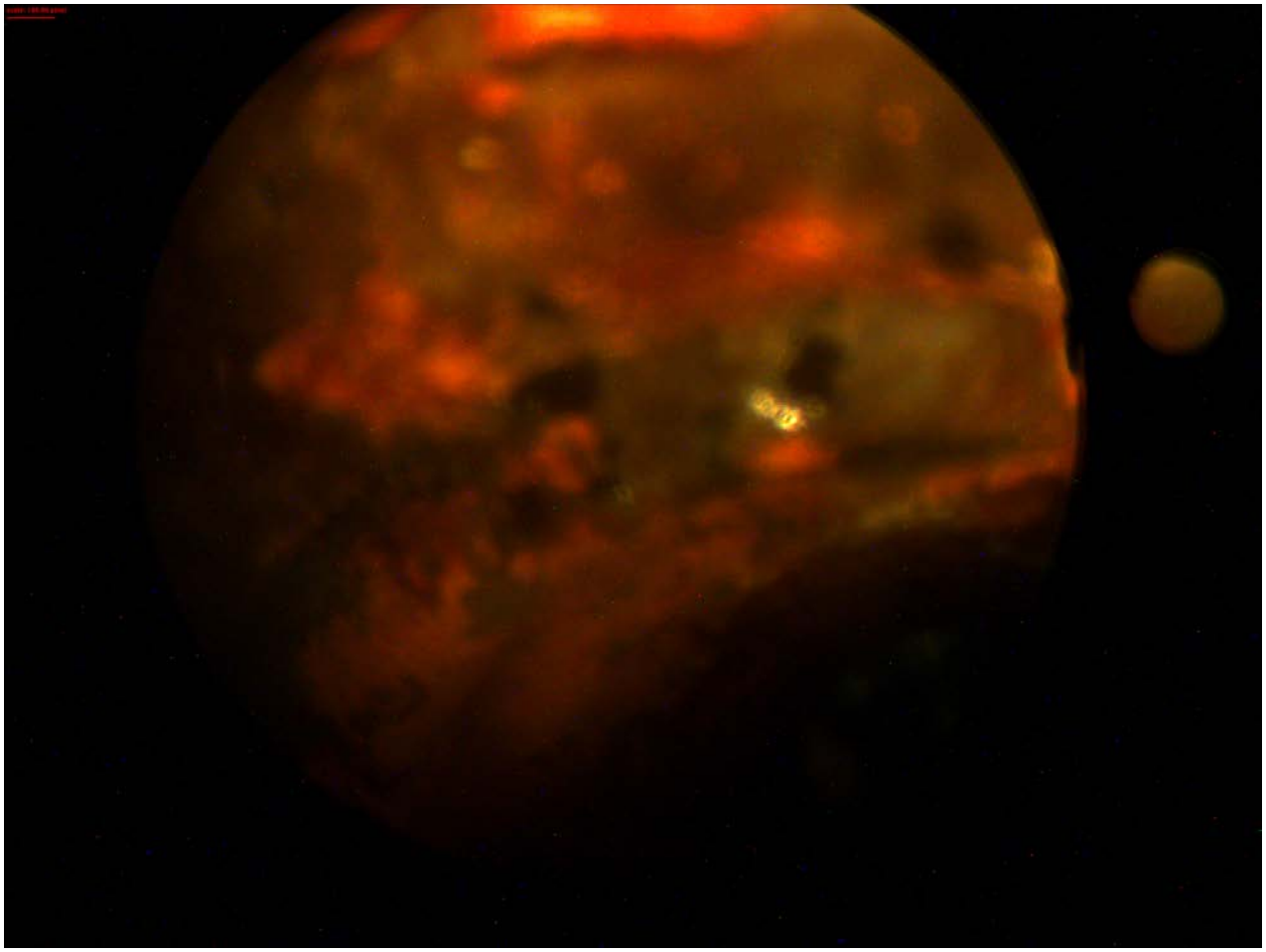
CSST – Interior Borescope



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CSST – Microscopy w/o Copper

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CSST – Microscopy w Copper

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CSST Arc Hole Size - BTU

Major D (mm)	Minor D (mm)	Area (in^2)	Drill Size	Cft/hr	BTU Capacity (BTU/cft)	BTU/hr
3.81	1.875	0.008696494	37	43.62	1000	43620
2.794	1.524	0.005183574	46	26.43	1000	26430
2.413	1.143	0.003357542	51	18.16	1000	18160
2.032	1.778	0.004398184	48	23.31	1000	23310
2.032	2.032	0.005026496	46	26.43	1000	26430
2.413	2.032	0.005968964	44	29.87	1000	29870

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CSST Arc Hole Size - BTU

Major D (mm)	Minor D (mm)	Area (in^2)	Drill Size	Cft/hr	BTU Capacity (BTU/cft)	BTU/hr
3.81	1.875	0.008696494	37	43.62	1000	43620
2.794	1.524	0.005183574	46	26.43	1000	26430
2.413	1.143	0.003357542	51	18.16	1000	18160
2.032	1.778	0.004398184	48	23.31	1000	23310
2.032	2.032	0.005026496	46	26.43	1000	26430
2.413	2.032	0.005968964	44	29.87	1000	29870

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GAC Fire #3

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GAC Fire #3

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GAC Fire #4

- GAC Connector Failed

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GAC Fire #4

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GAC Fire #4

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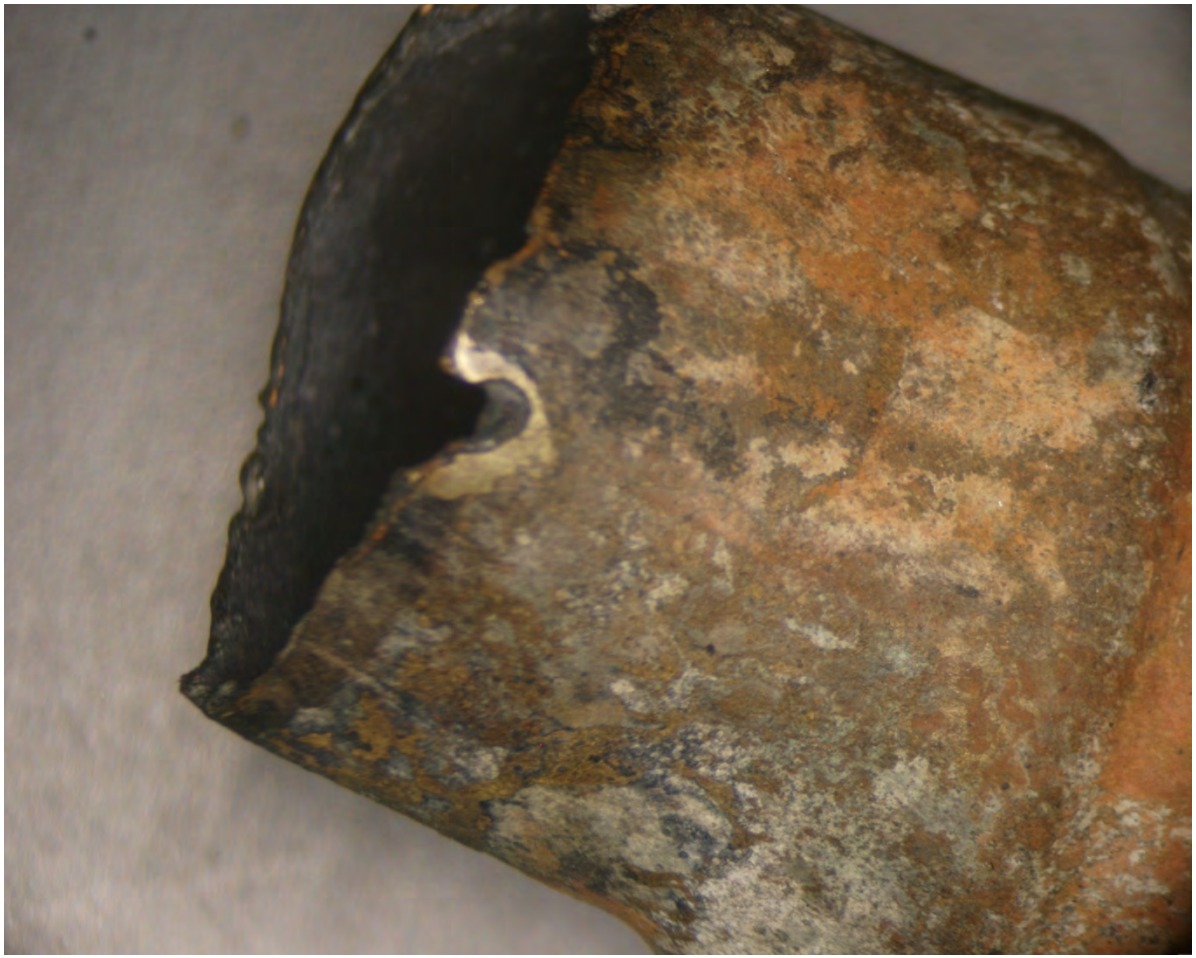
GAC Fire #4



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GAC Fire #5

- Gas Appliance Connector Failed
  - Energized gas line
    - Conduit energized by compressor electrical wires shorting out to frame or case of unit
  - House built in 1978

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GAC Fire #5

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GAC Fire #5

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GAC Fire #6

- Gas Appliance Connector Failed

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GAC Fire #6

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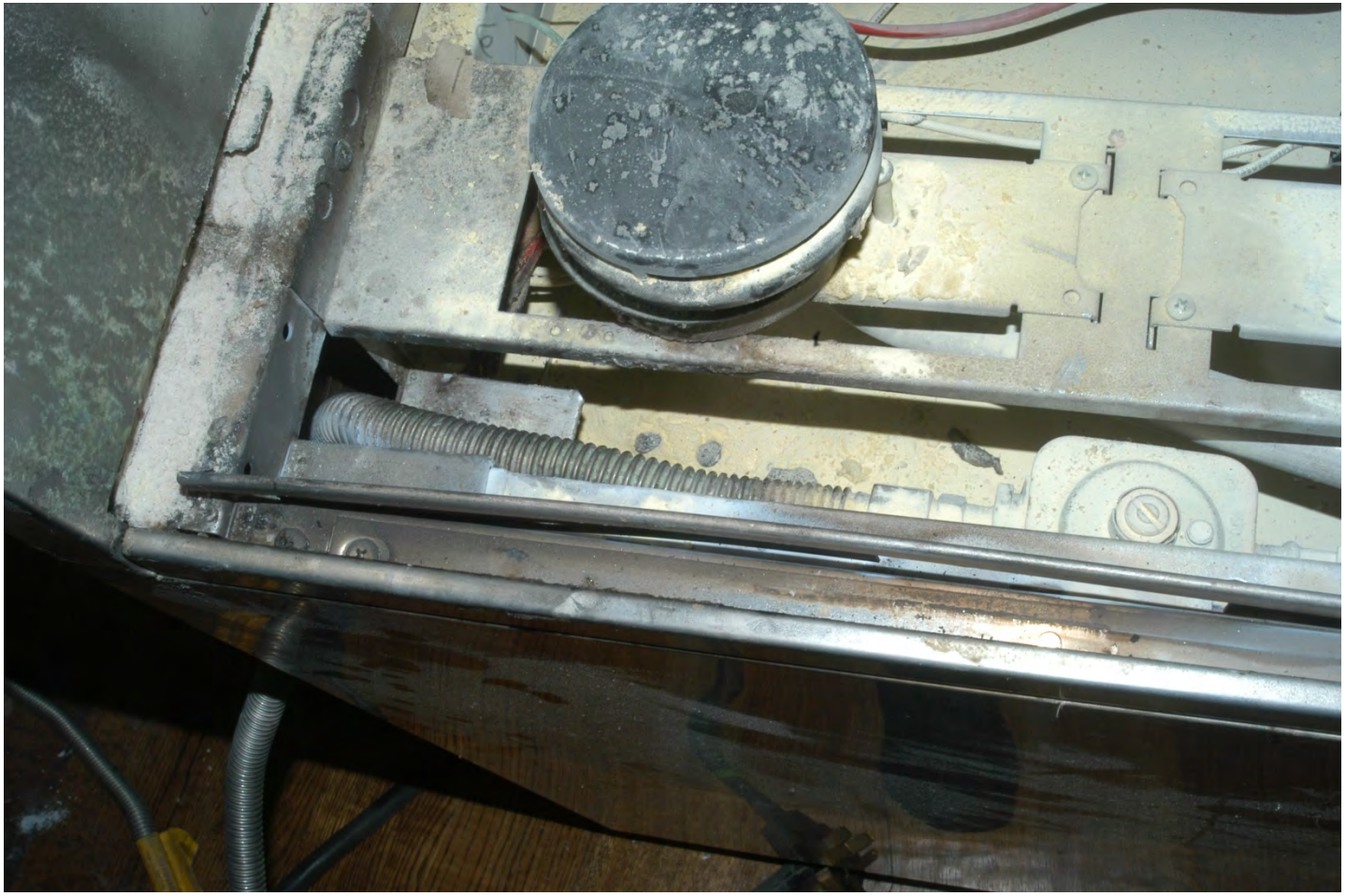
GAC Fire #6



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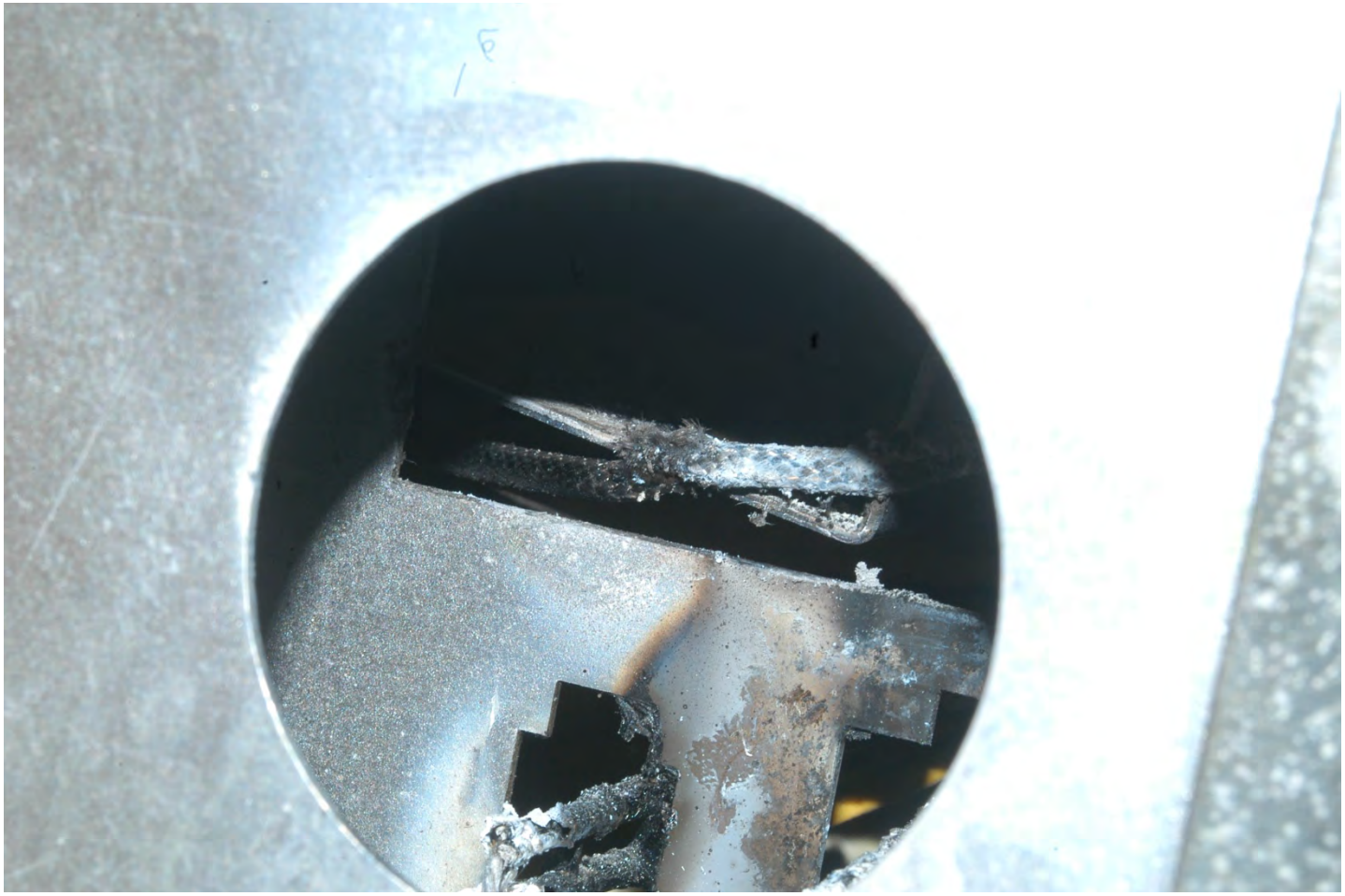
GAC Fire #6

1500 Spencer Rd ● Denton TX 76205

GAC Fire #6

1500 Spencer Rd ● Denton TX 76205

GAC Fire #6



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CSST Fire #2

- Energized Gas Line
  - Single Story Home
  - Lightning Stroke to Telephone Box
  - Gas Riser Black Pipe
  - CSST connected to Riser
  - Perforation in CSST about 3 inches from Gas Riser
  - Thunderstorm present Vaisala reported 248 strikes within 5 miles

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CSST Fire #2

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CSST Fire #2

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CSST Fire #3

- Energized Gas Line
  - Single Story Brick Home
  - Hole in CSST about 2 feet above floor of attic near chimney
  - Copper Splatter Present on CSST
  - V pattern on chimney flue
  - CSST Manifold not Grounded
  - Thunderstorms present before event

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CSST Fire #3

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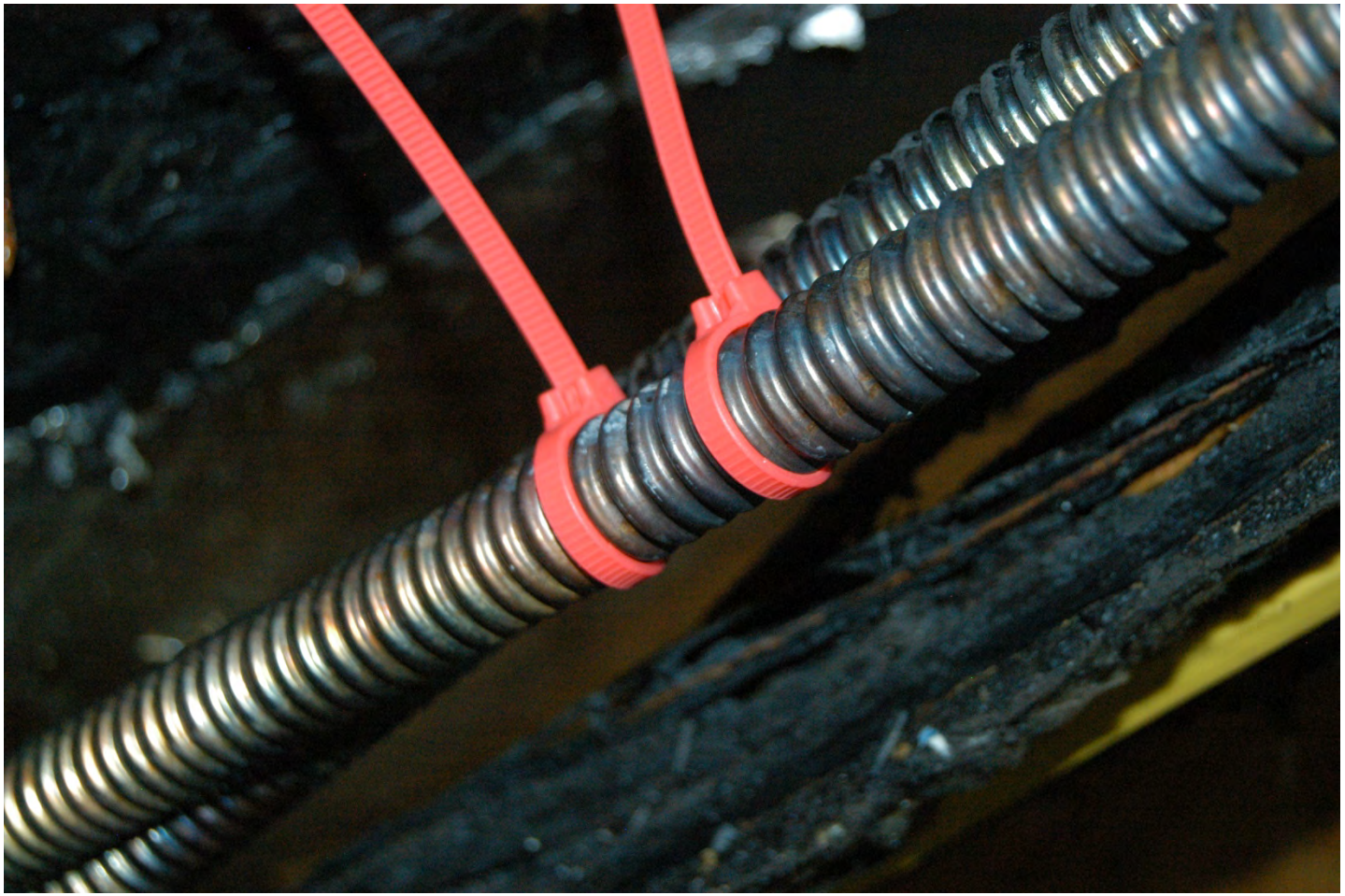
CSST Fire #10



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CSST Fire #10

1500 Spencer Rd ● Denton TX 76205

CSST Fire #10

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