NFPA CSST PROJECT - LIGHTNING & ELECTRICAL ARC DAMAGE TO CSST

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Electrical Arc Damage to CSST

- Hole size proportional to energy dissipated
  - Power proportional to product of current and voltage
  - Voltage at arc/metal interface approximately constant
  - Energy proportional to time integral of current (charge)
- For CSST of 0.25mm wall thickness
  - Hole area in sq mm ~ 3 x charge in coulombs
  - 2mm diameter ~ 1 coulomb

Direct Lightning Strikes

- Most often to ungrounded metallic roof penetrations
  - Melting on metal components most liable to be struck
    - Chimney flues
    - Heater vents
  - Mechanical damage to non-conductors
- Current flows through all available paths to earth
  - Electrical, telephone and cable TV lines
  - Structural metalwork, metal-foil-clad insulation
  - Water, HVAC and gas pipes
    - Model simulation
- May also initiate power system faults

Ungrounded Roof Penetrations

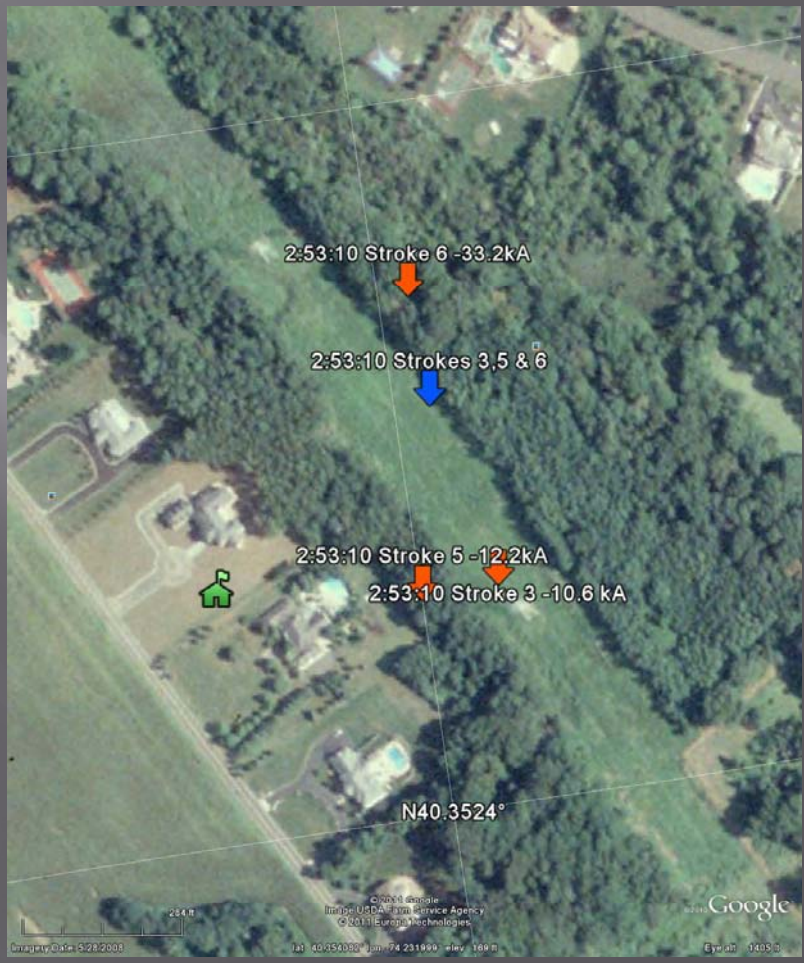
- Chimney caps and flues
- Furnace vents
- TV antennas
- Satellite dishes

Indirect Lightning Strikes

- Lightning-related event with no evidence of direct strike to structure
- Evidence of nearby strike
  - Damage to trees or non-metallic objects
  - Melting on nearby metallic objects
  - Power line damage

Lightning Location Data

- Not precise enough to locate exact point of strike
  - Location done by radio location of lower channel ~ 500m errors
- Will locate many (not all) strokes of multi-stroke flash
- May identify separate channels



Direct Strike Currents

- Negative flashes:
  - One or more impulsive return strokes
    - 30 kA 10x100 μs (5 coulomb impulse charge)
  - One continuing current in some flashes
    - 100 A, 100ms (10C)
- Positive flashes
  - One return stroke
    - 100 kA 30x300 μs (100C)

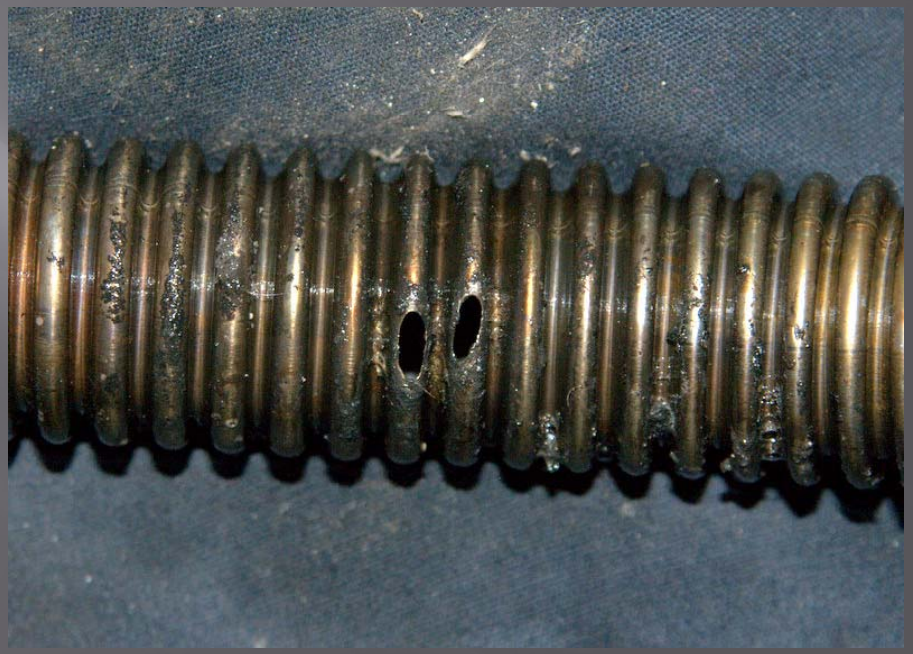
Indirect Strike Currents

- Unconnected leader to metallic roof penetrations
  - Short duration (μs), high voltage (>100 kV), low energy and charge (~0.001C)
- Electromagnetically-induced surges
  - Medium duration (10 μs), high voltage, low energy and charge (~0.001C)
- Surges on incoming services
  - Ground-potential rise
  - Longer duration (100 μs), medium voltages (10 kV), moderate energy and charge (~0.01C)

Unconnected Lightning Leaders

Evidence for Power System Faults

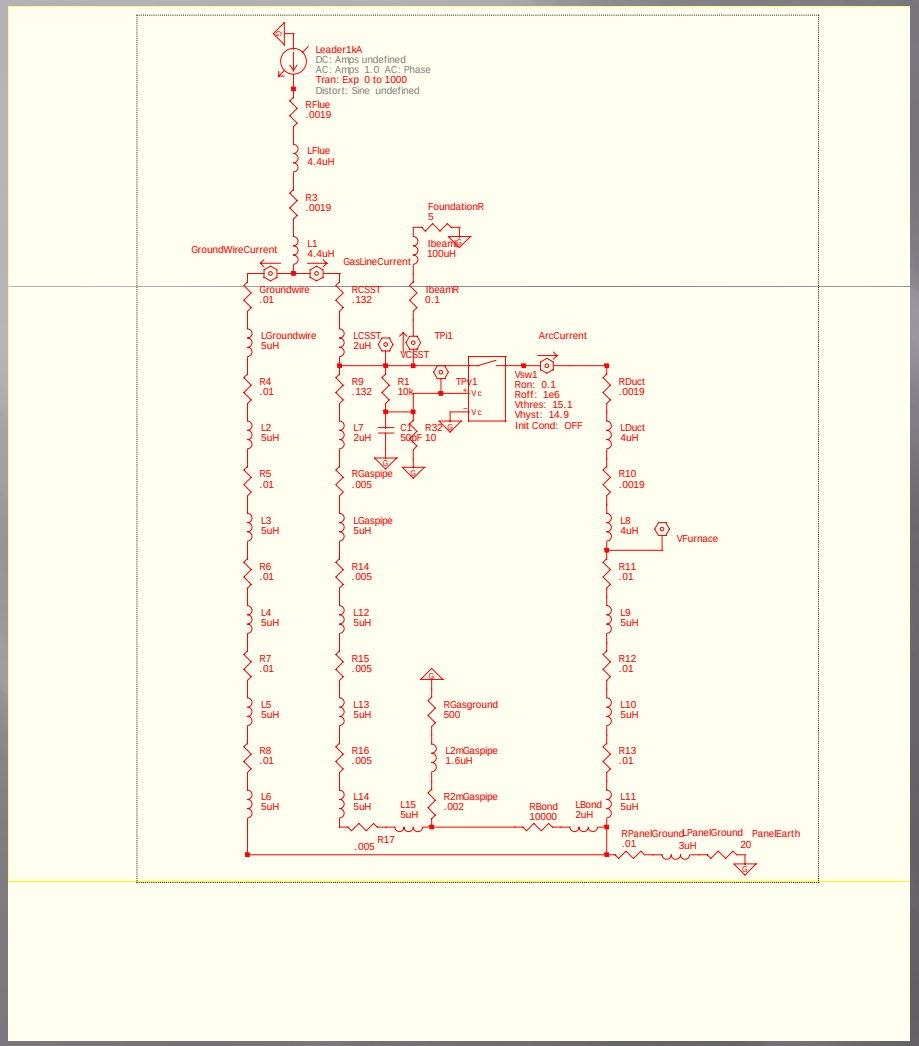
- Multiple adjacent holes of similar size
  - Frequently reported from indirect lightning
  - Adjacent arcs unlikely to exist concurrently
  - Likely serial from multiple-stroke lightning flash
  - Power system only source likely to deliver similar energy in successive arcs
- Computer simulation

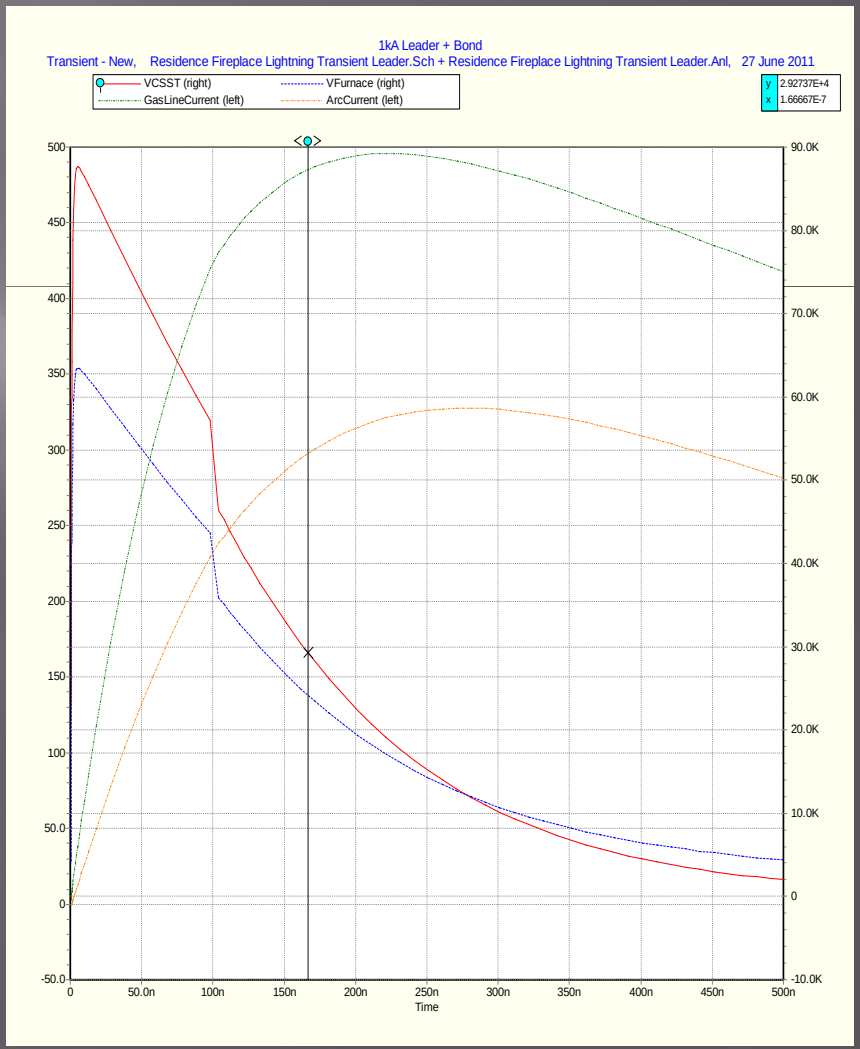


Two CSST Arc Damage Mechanisms

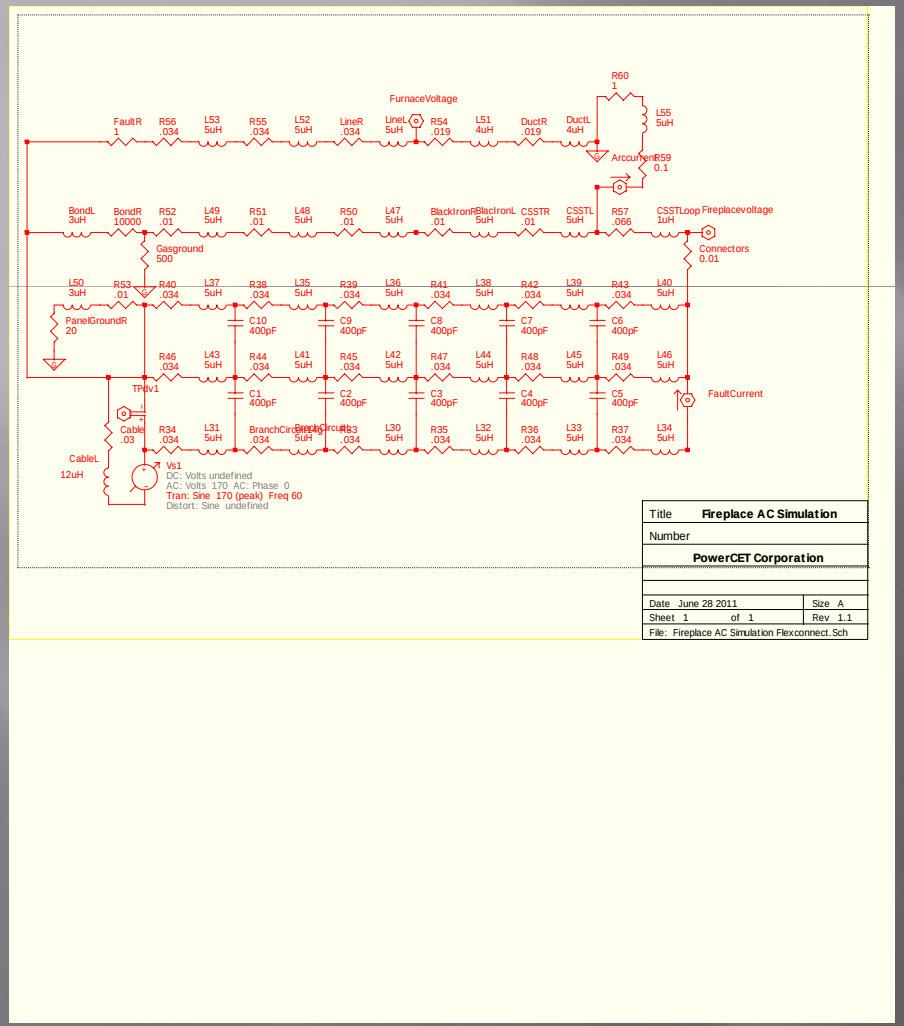
- Direct Lightning Strikes
  - Fraction of lightning current flows onto CSST through arc
    - Return stroke
    - Continuing current
  - Sufficient current magnitude and duration to cause observed damage
- Indirect Lightning Strikes
  - Indirect lightning currents too small and too short duration to damage CSST
  - Indirect overvoltage (> 50 kV) causes multiple flashovers, including AC power system
  - AC power fault current flows through arc
  - Sufficient current magnitude and duration to cause observed damage
  - Power fault currents also likely cause of many fires not involving gas pipes

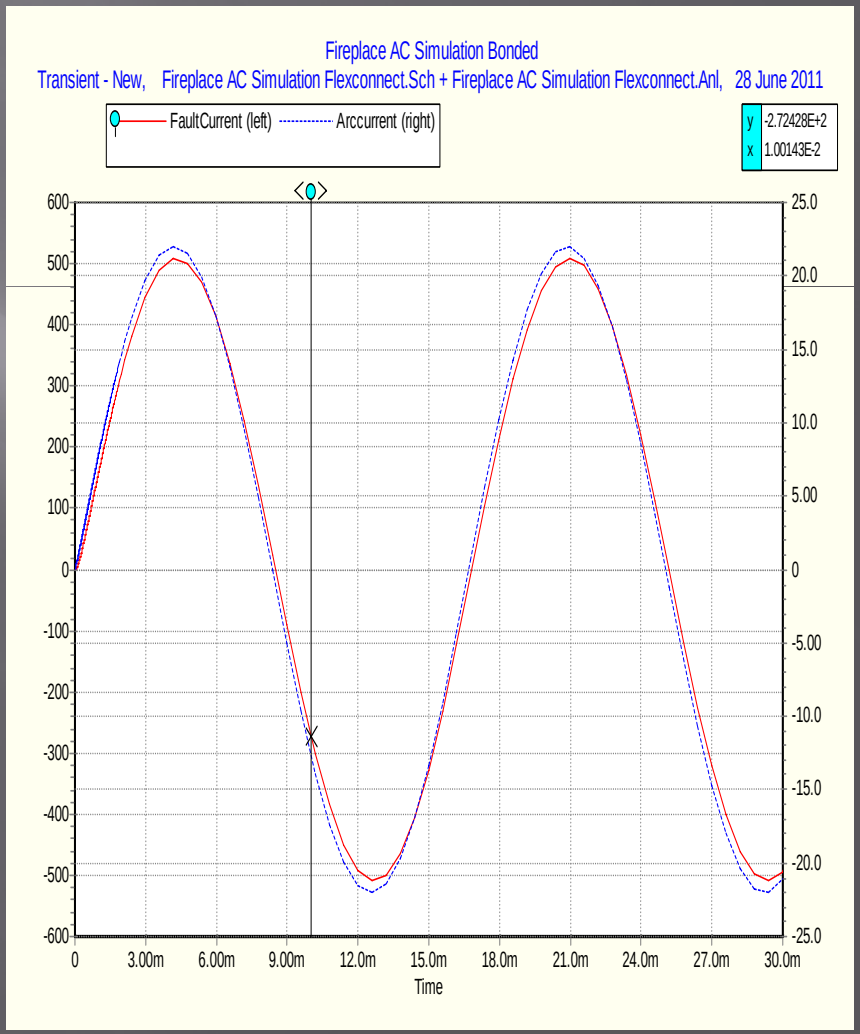
SPICE Simulation (Leader Current)





SPICE Simulation (AC Fault Current)





Solutions to Gas Pipe Damage

- Direct Strikes
  - Install at least minimal lightning protection system
  - Bond all metal services to main building and power system ground
    - Including gas pipes on building side of service
      - All gas pipes, not just CSST!
- Indirect Strikes
  - Ground ungrounded roof penetrations
    - Preferably through lightning protection system
  - Bond all metal services to main building and power system ground
    - Including gas pipes on building side of service
  - Evaluate benefit of earth-leakage relays on AC power system

Questions

- Should there be a mandated minimum requirement for lightning protection in vulnerable structures, including residences?
- Do we need to define lightning withstand requirements for services in unprotected structures? (Proceed with caution!)
  - Electrical lines & equipment
  - Gas pipes & appliances
  - Telephone & cable wires & equipment
  - Water pipes

Further Work

- Include ALL gas pipe systems in study
  - Compare and contrast type and incidence of damage to rigid pipe systems to that of CSST
  - Long reported lightning damage to rigid pipe systems not investigated or understood
    - Joints, flex connectors or appliance valves?
- Identify relative importance of direct and indirect strikes for gas and electrical fires
  - Computer simulation very helpful
  - Solutions may be different
- Would replacing CSST by rigid pipes improve overall fire incidence?
  - Leaks & breaks much more significant cause of fires than lightning