Fire Testing of Electric Cables for Public Transportation

Marcelo M. Hirschler

GBH International


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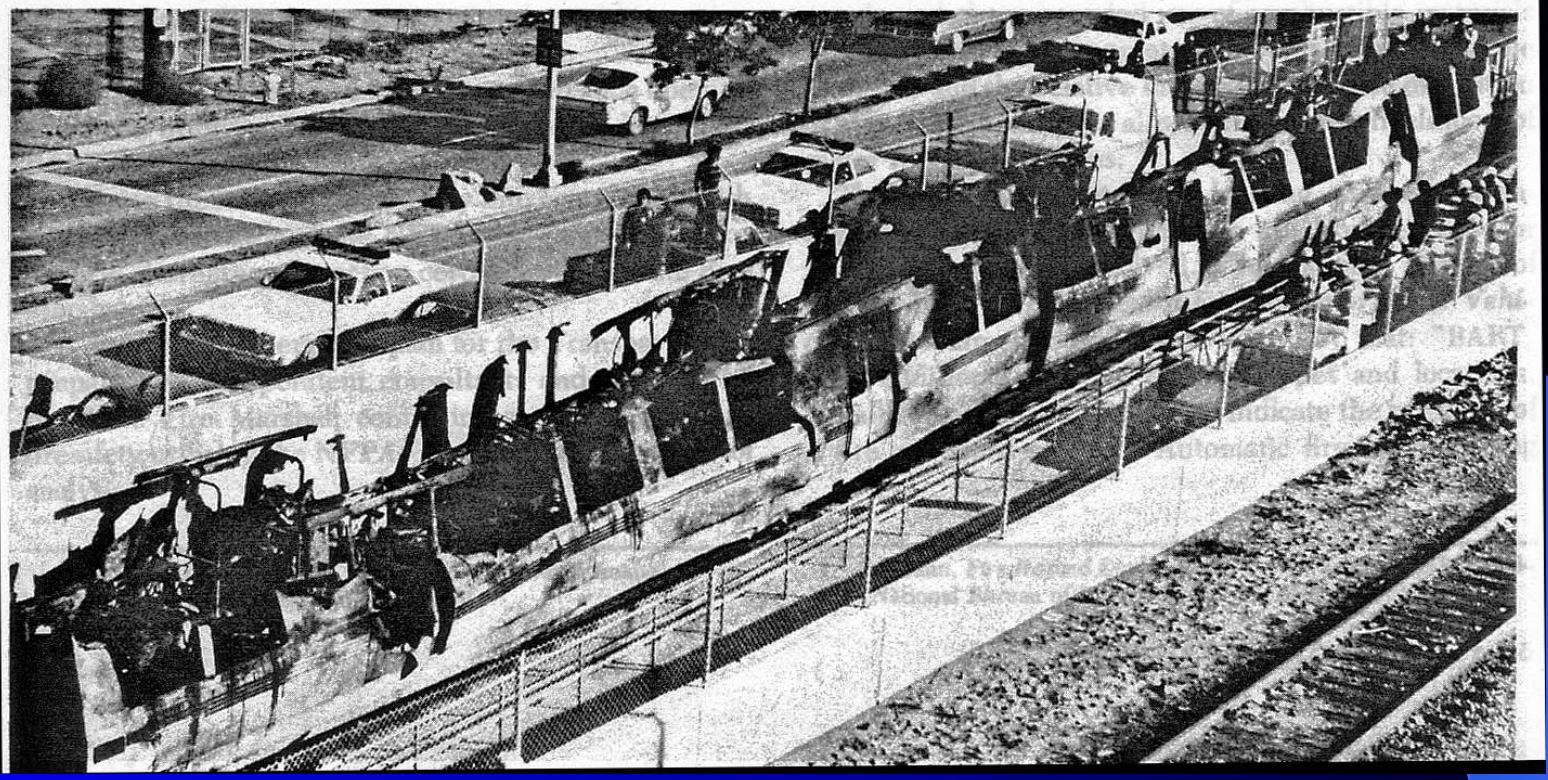
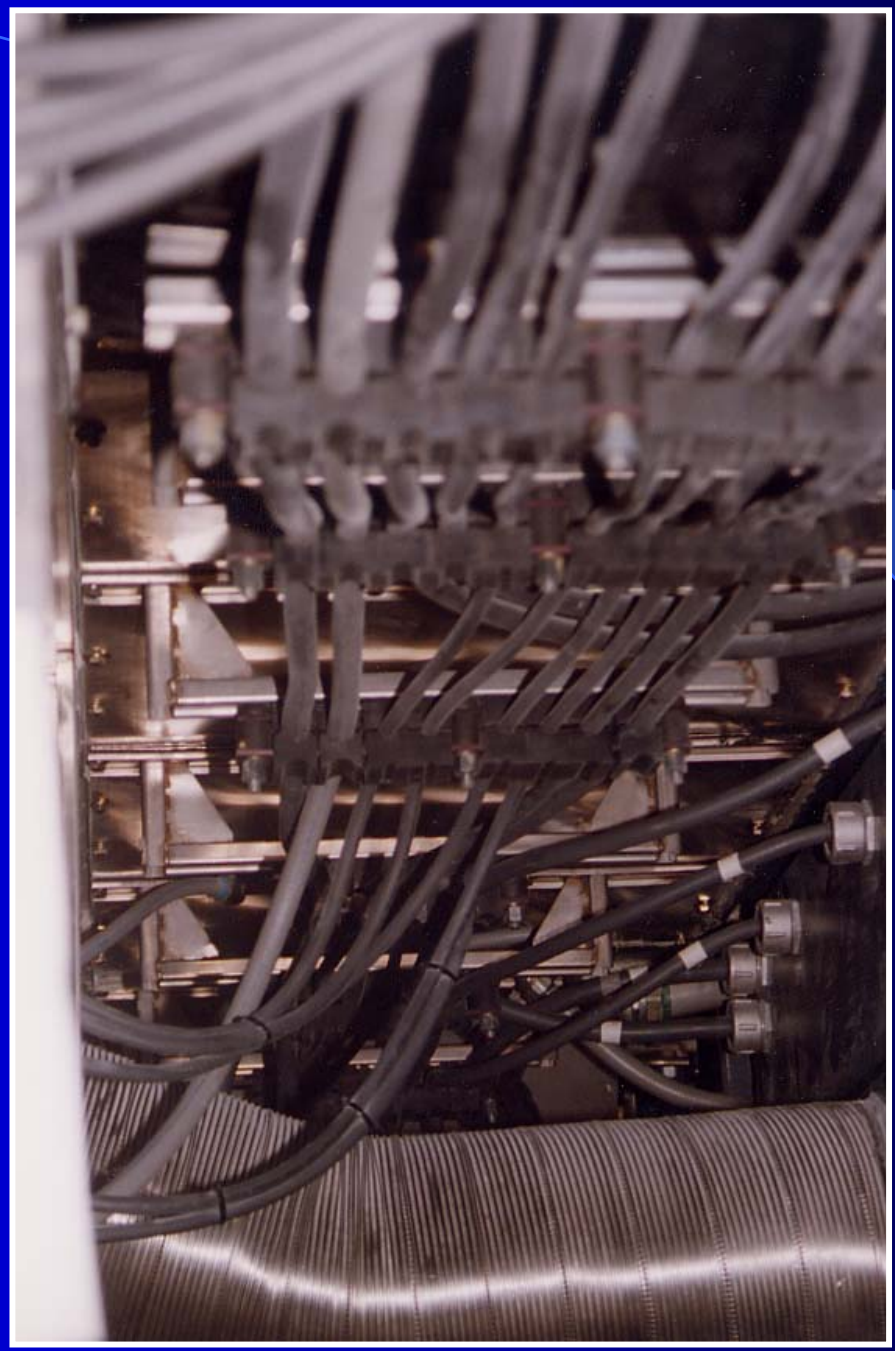
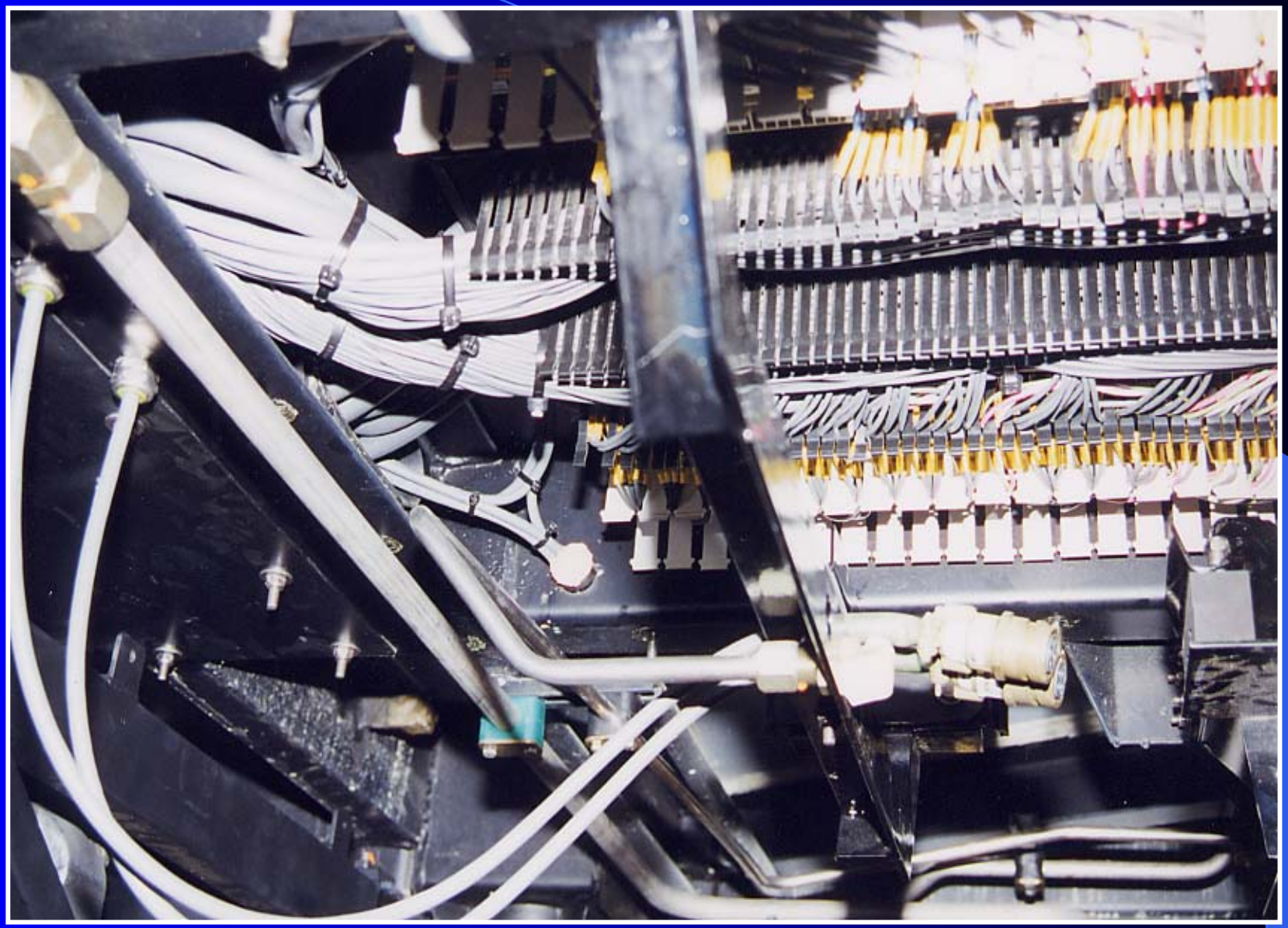
Two of the five totally destroyed cars after the January 17, 1979 BART fire. *San Francisco Chronicle*





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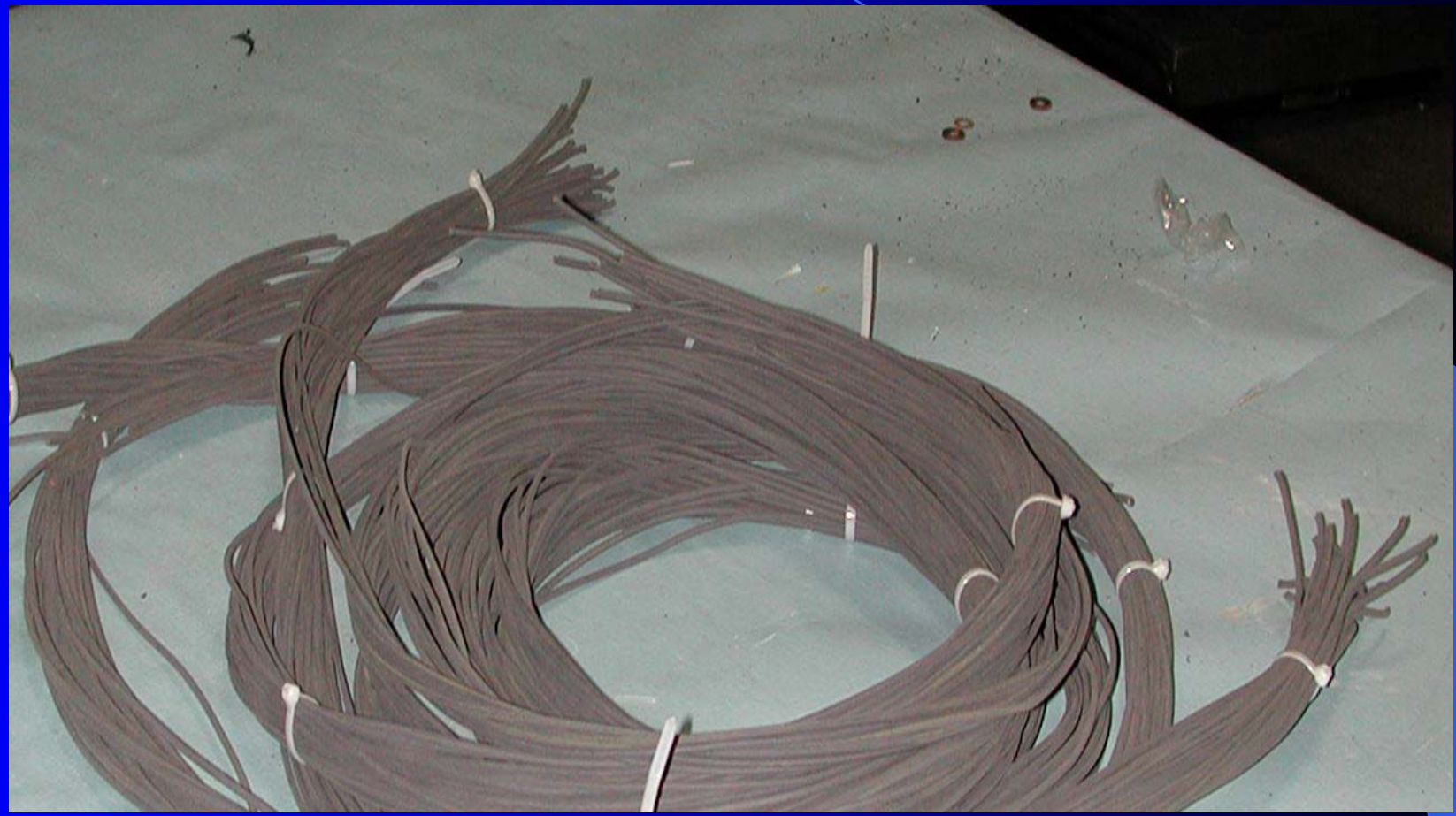


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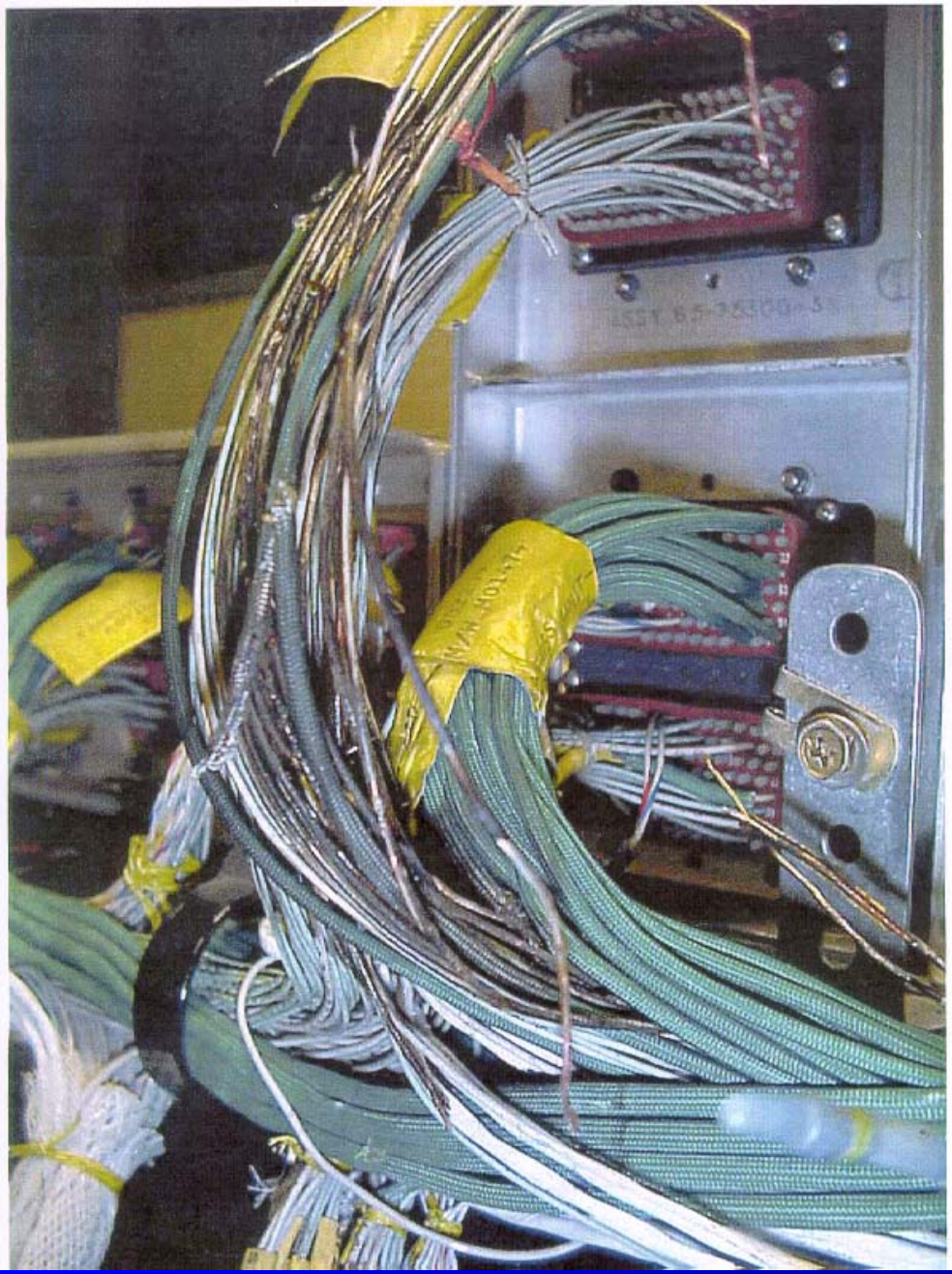

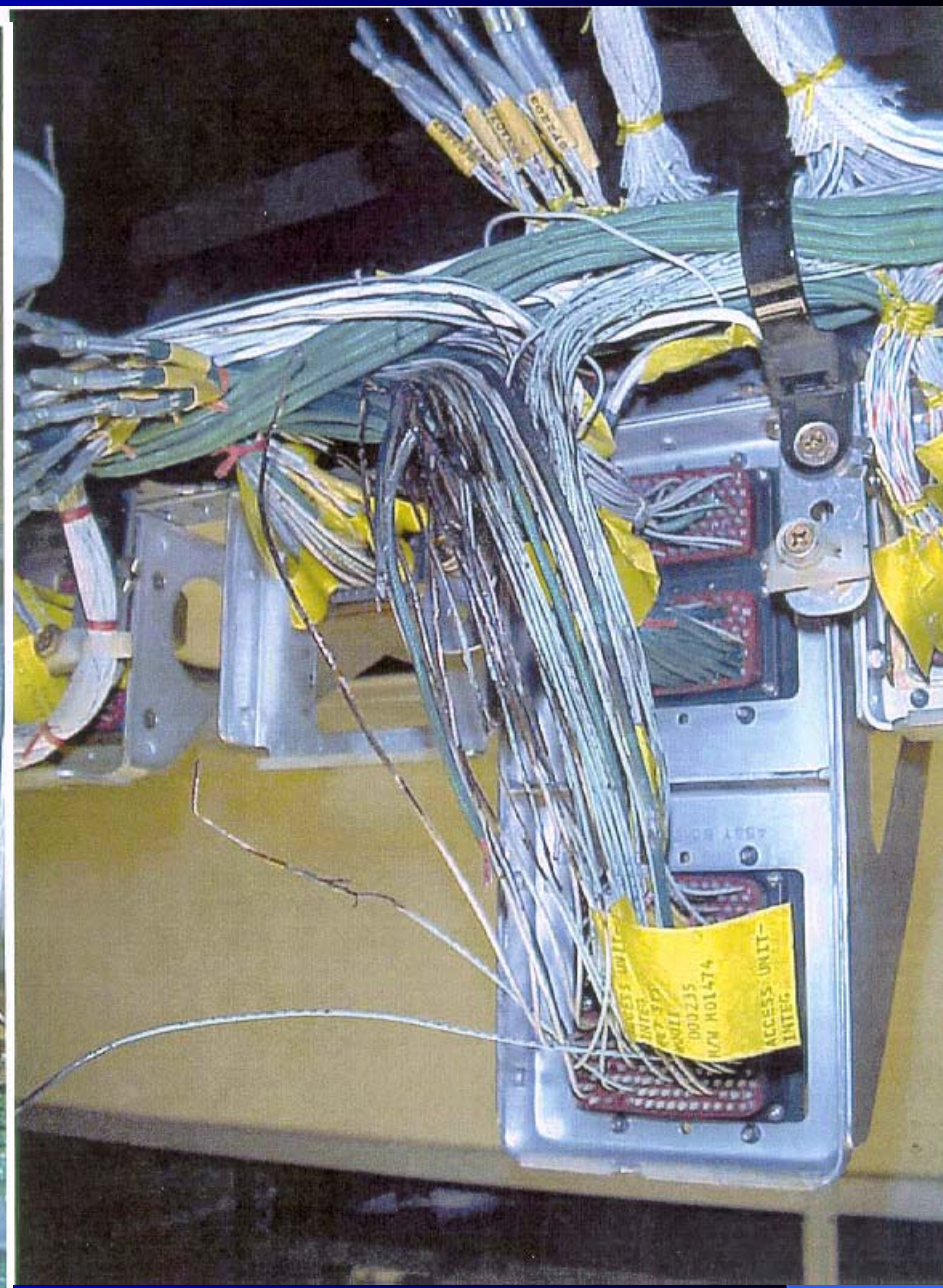
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Fire Issues

- Cables are Important Contributors to Fire
- Cables are Growing Transport Fuel Load
- Most Transportation is Updating Tests
- Smoke Obscuration Needs to be Considered
- Tests Must Address Proper Fire Hazard

Statistics: Item First Ignited
(Electrical Wire & Cable Insulation Data)

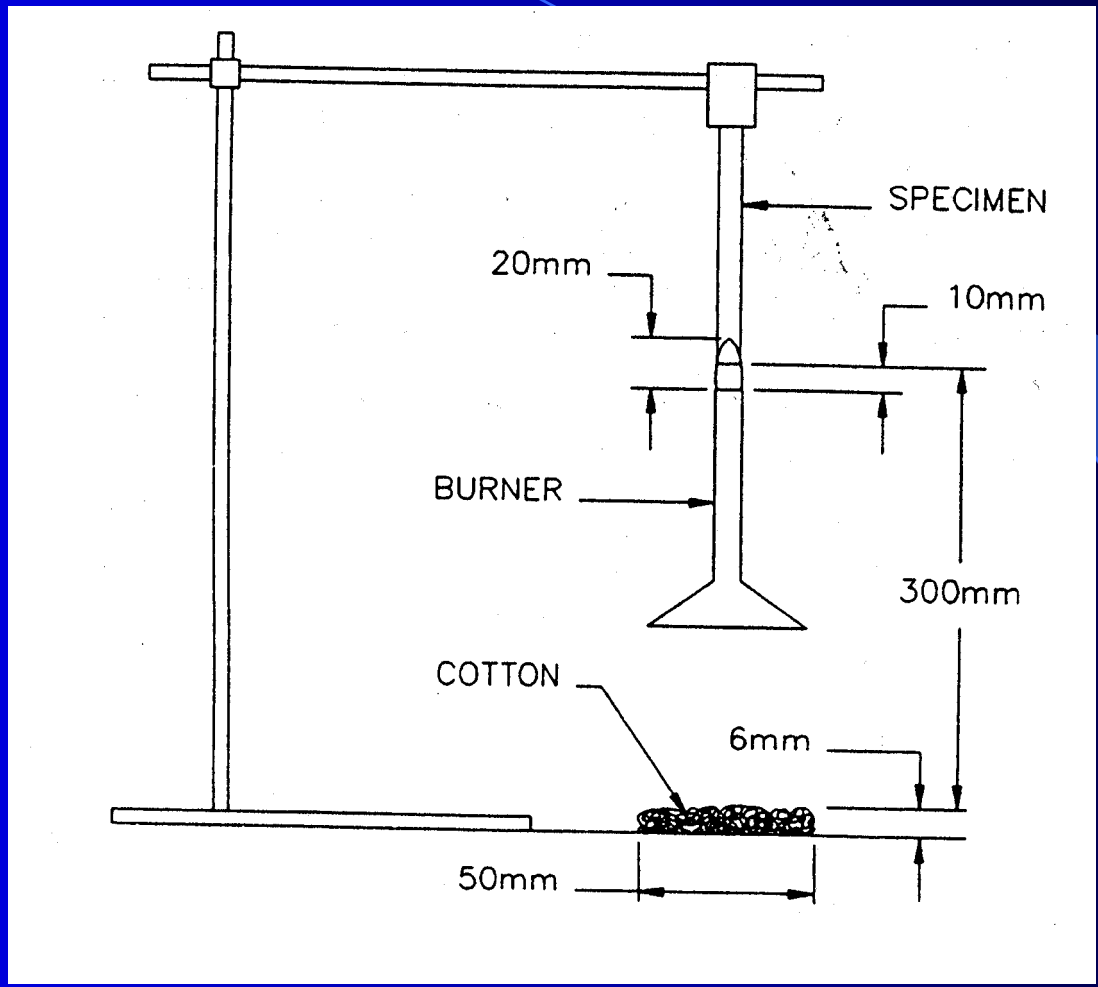
Type of Vehicle	% Fires
Passenger Road	25.6
Freight Road	22.0
Air Transport	11.8
Water Transport	13.3

Types of Cable Fire Tests

- Old Fashioned Small Scale Material/Cable
- Vertical Cable Tray
- Steiner Tunnel (NFPA 262)
- Small Scale Heat Release Cable
- Tests for Ancillary Properties

Old Small-Scale Tests

- Flammability of Materials (e.g. UL 94)
- Flammability of Cables (e.g. UL VW1 or FAA 60 Degree Angle Test)
- Little Radiant Heat Input: 0.5 to 1 kW
- Low Relevance to Real Fires



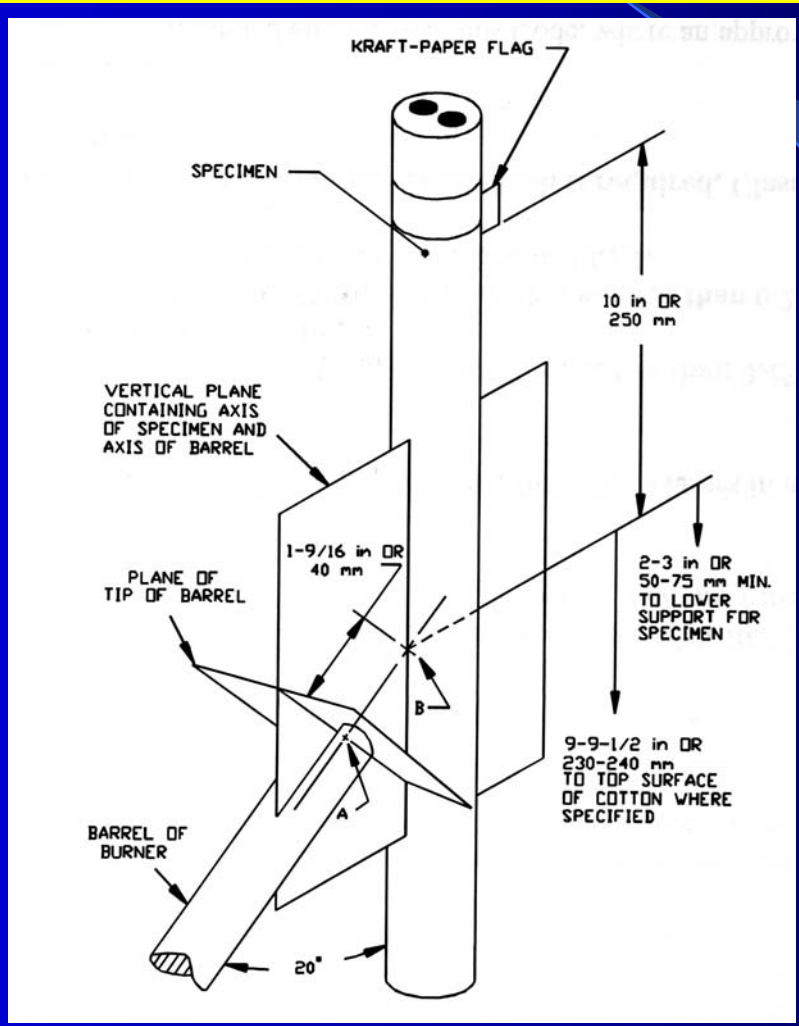
UL 94 V Test Layout

UL 94 Test Chamber

VW-1 Test

- Uses Bunsen Burner Igniter
- Single Length of Cable Exposed
- Least Severe of All Cable Tests in NEC

VW-1 Burner


KRAFT-PAPER FLAG
SPECIMEN
10 in OR
250 mm
VERTICAL PLANE
CONTAINING AXIS
OF SPECIMEN AND
AXIS OF BARREL
1-9/16 in OR
40 mm
PLANE OF
TIP OF BARREL
2-3 in OR
50-75 mm MIN.
TO LOWER
SUPPORT FOR
SPECIMEN
B
9-9-1/2 in OR
230-240 mm
TO TOP SURFACE
OF COTTON WHERE
SPECIFIED
A
BARREL OF
BURNER
20°

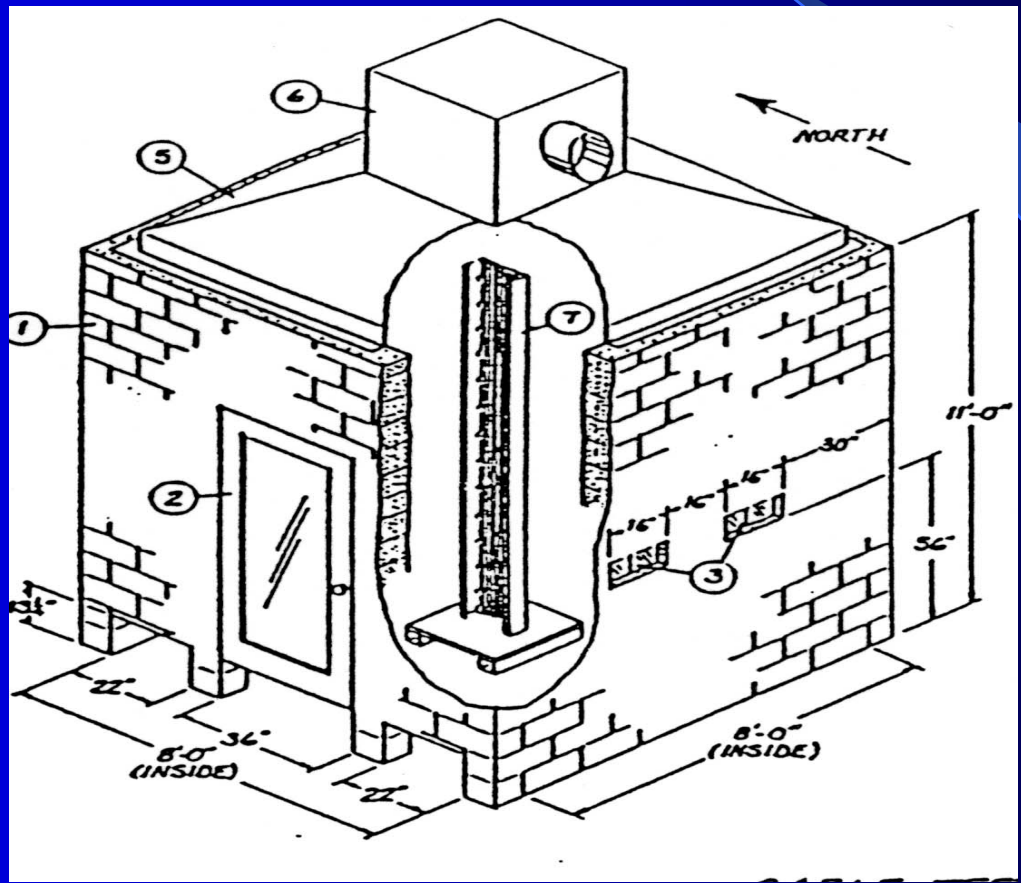
Old Small-Scale Tests

- Many Examples: ASTM, UL, IEC, ISO
- Do Not Require Excellent Performance
- Cable Tests Easy to Pass if Thick
- Generally Lowest Level Requirement

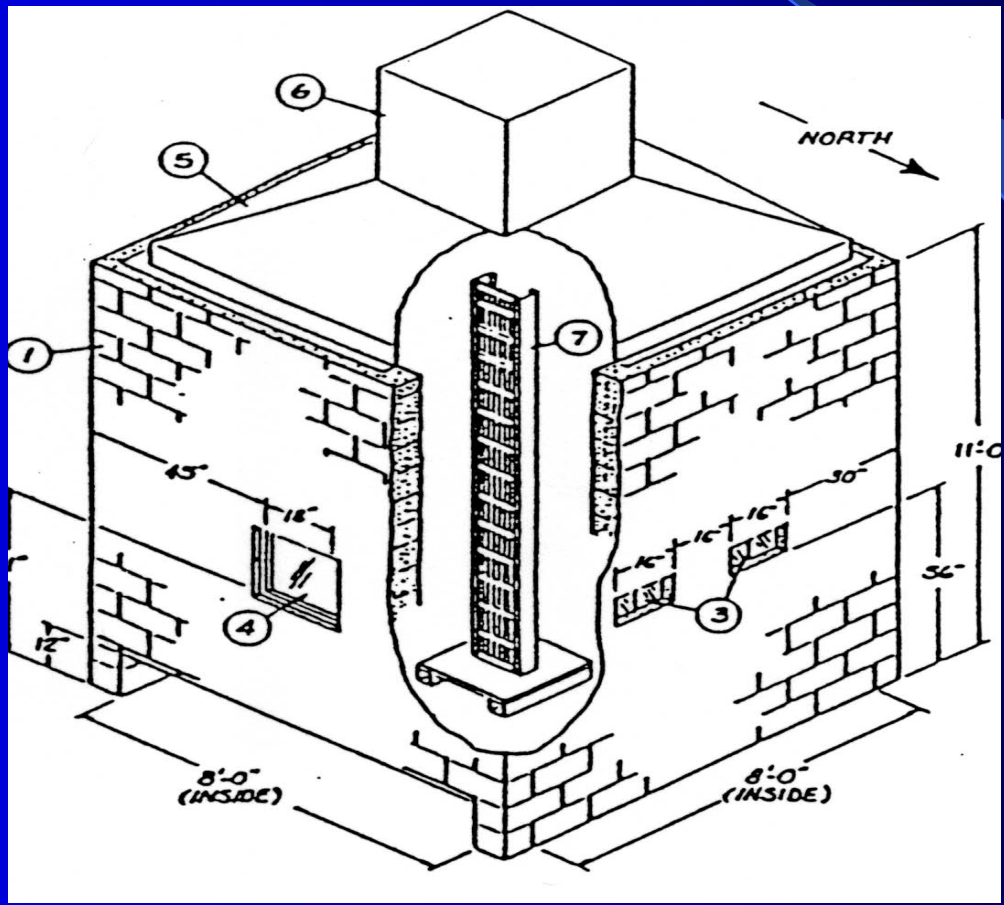
Vertical Cable Tray Tests

- UL 1581 & CSA FT 4: Various Names
- Significant Differences Between Them
- Radiant Heat Input: 20 kW
- Good Relevance to Real Fires
- Can be Used to Measure Heat & Smoke

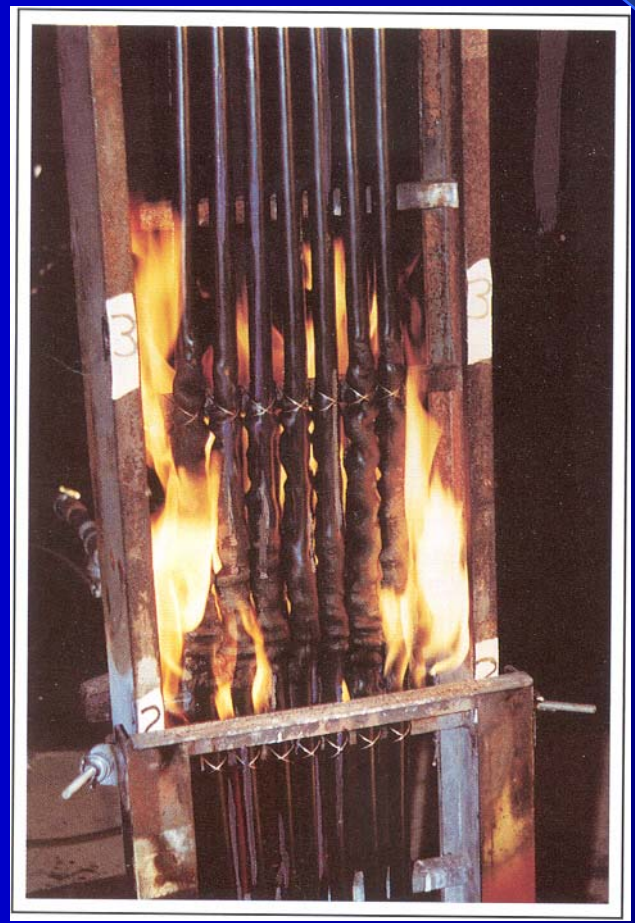
UL 1581 Cable Tray Test: Front



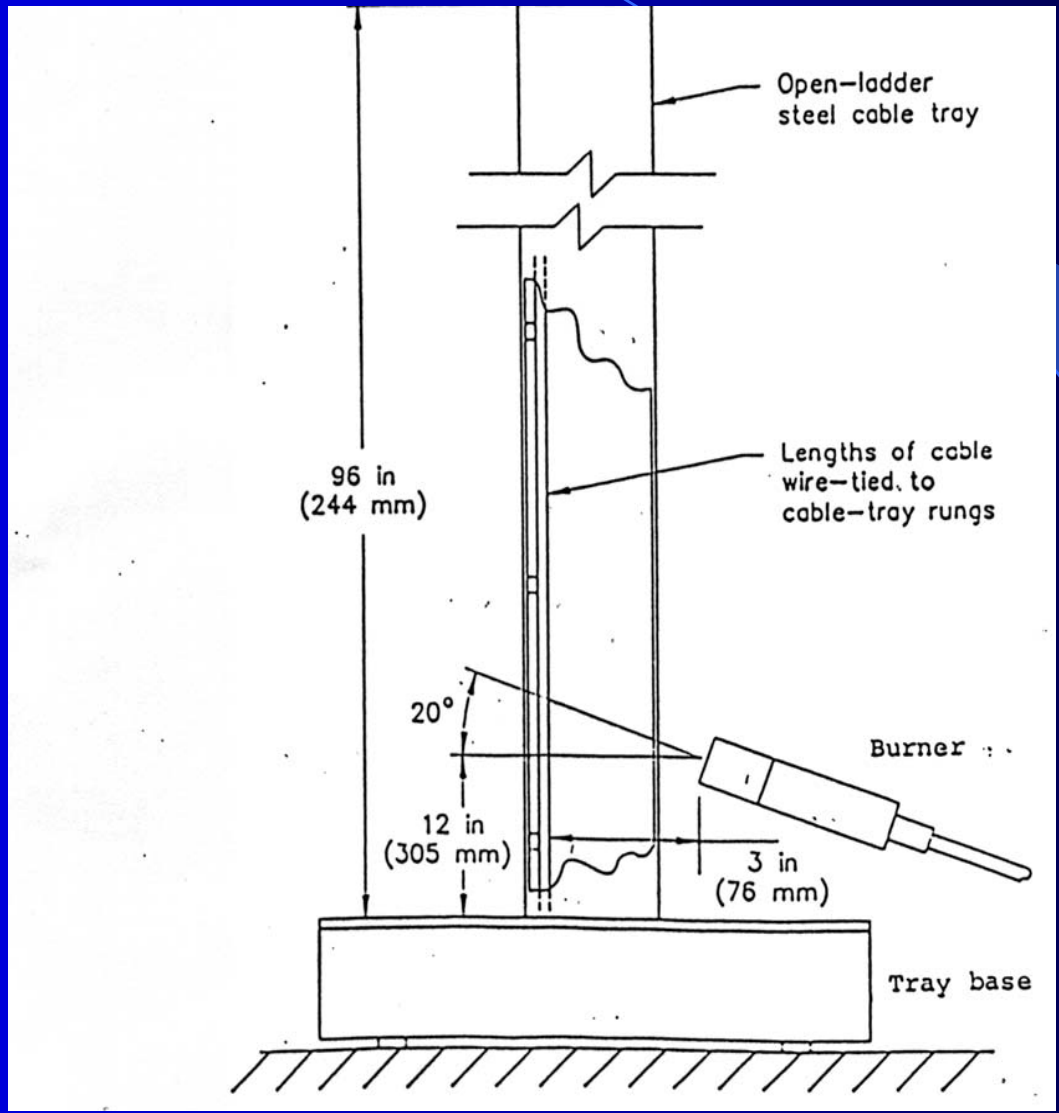
UL 1581 Cable Tray Test: Back



UL 1581 Cable Tray Test: Burn



CSA FT4 Cable Tray Test: Burner and Tray



Comparison Between Cable Tray Tests

- UL 1581 has Burner Perpendicular
- CSA FT4 has Burner at 20° Angle

- UL 1581 Has Less Severe Cable Loading

- UL 1581 Requires < 8 ft Flame Spread
- CSA FT4 Requires ≤ 1.5 m Flame Spread

- CSA FT4 is Much More Severe

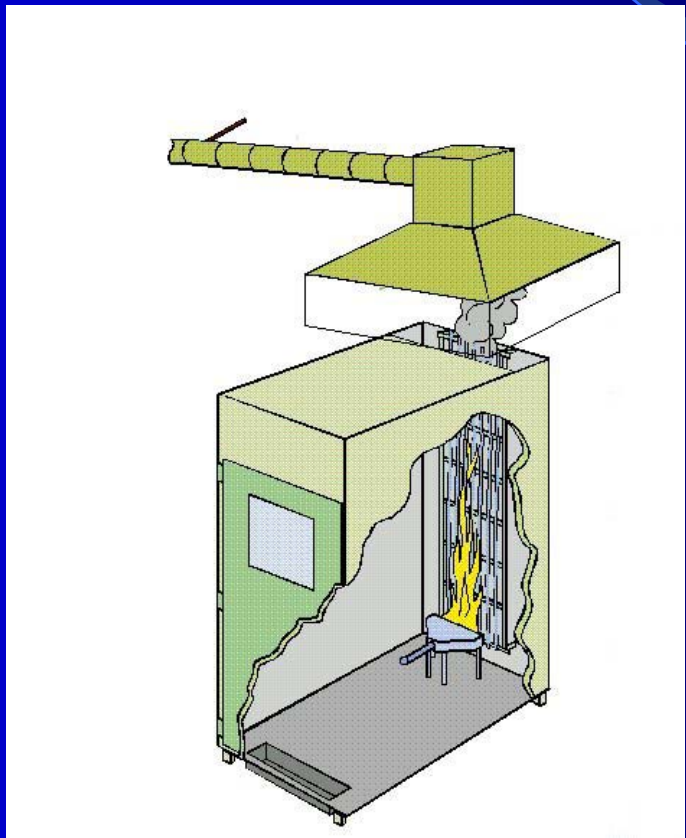
Different Test Designations

- UL 1581-1160 same as UL 1685/"UL"
- or IEEE 383 or ASTM D 5537/"UL"

- CSA FT4 same as UL 1685/"CSA"
- or IEEE 1202 or ASTM D5537/"CSA"

- IEEE 383 is Obsolete, per IEEE

European Vertical Cable Tray Test



IEC 60332-3

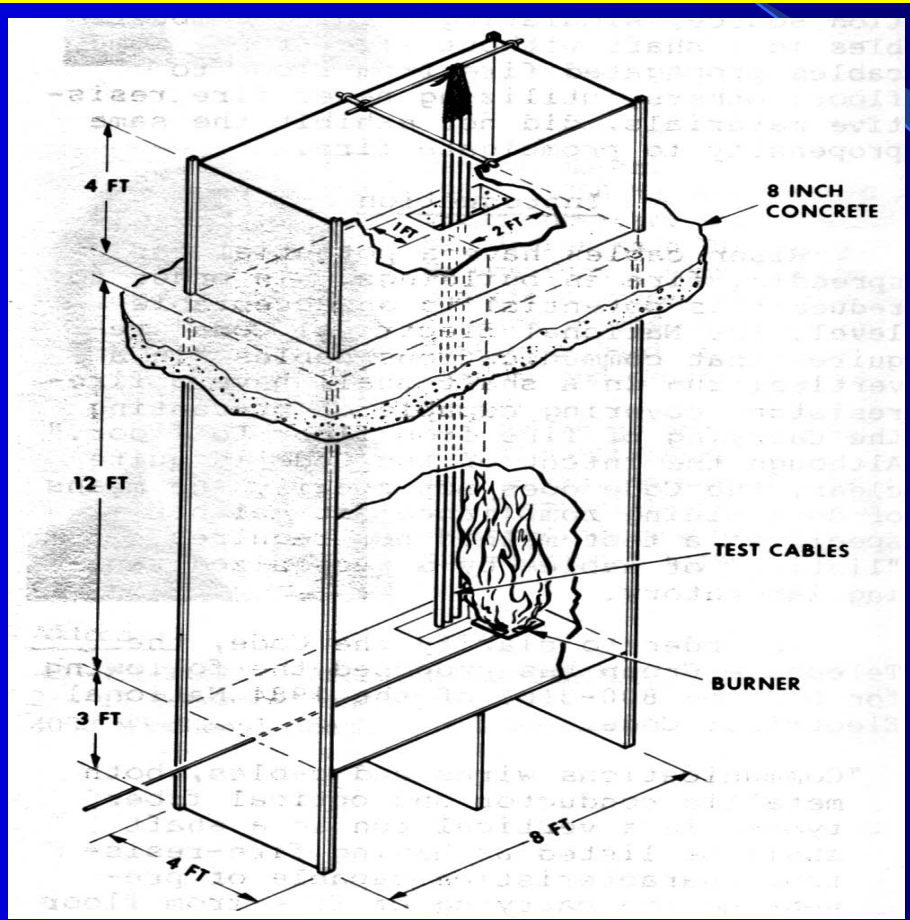
European Vertical Cable Tray Test

- Required for Cable Regulation in Europe
- Recently Amended by European Community "FIPEC" Research Project
- Measures Heat, Smoke Release & Flame Spread, as Well as Flaming Drips

Riser Cable Test

- Vertical Test: Gas Flame Underneath
- Cable Cannot Spread Flame from Floor to Floor
- Much More Severe than Cable Tray Test

UL 1666 Cable Test Apparatus

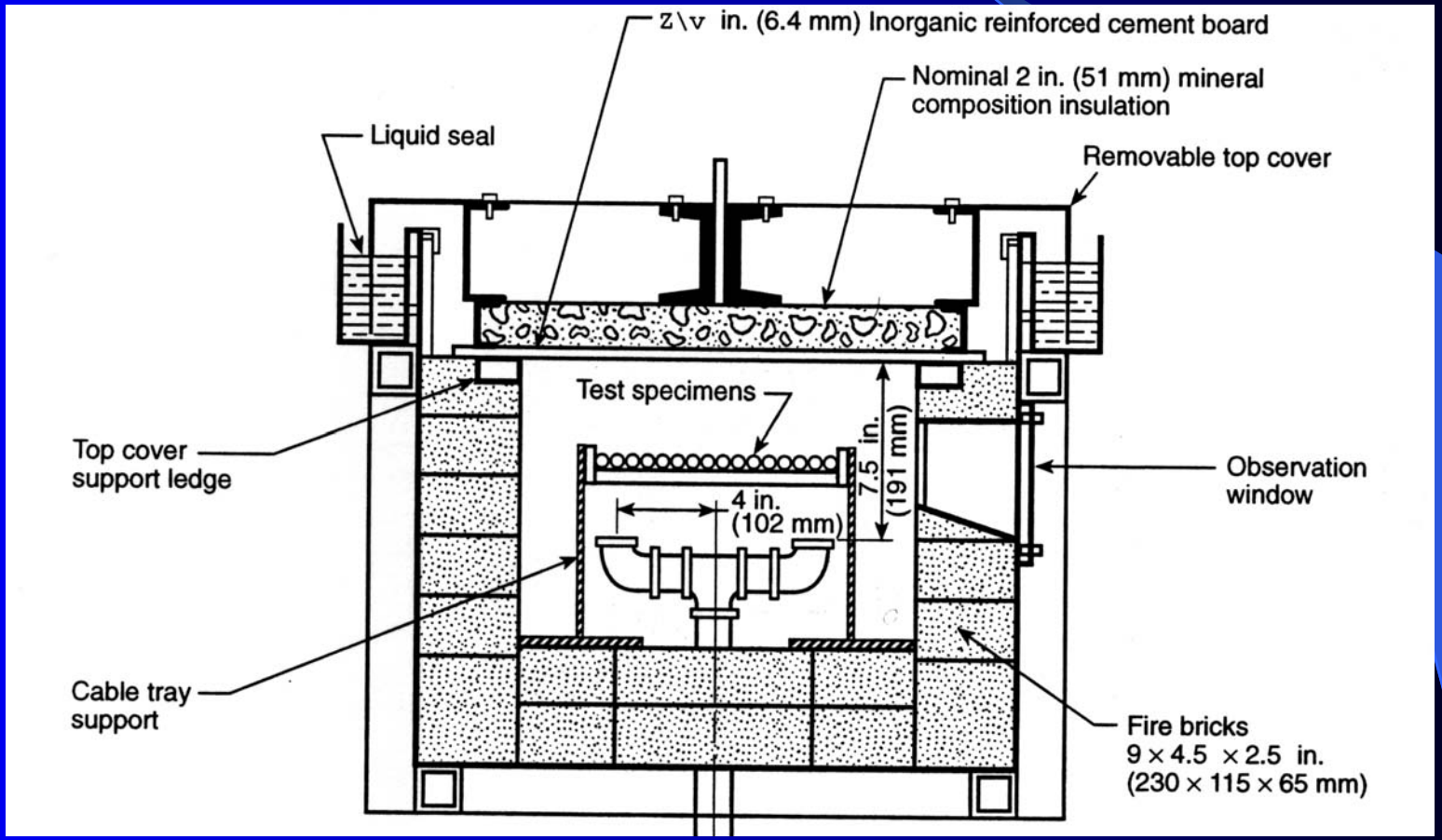


Plenum Cable Test

- Horizontal Test: Gas Flame & High Flow
- Cable Cannot Spread Flame > 5 ft
- Much More Severe than Riser Test
- Also Measures Smoke Obscuration

Steiner Tunnel
(Severest Cable Fire/Smoke Test)

Burner for Steiner Tunnel



Flame in Steiner Tunnel

Different Test Designations

- NFPA 262 same as UL 910
- Plenum Flame and Smoke Test

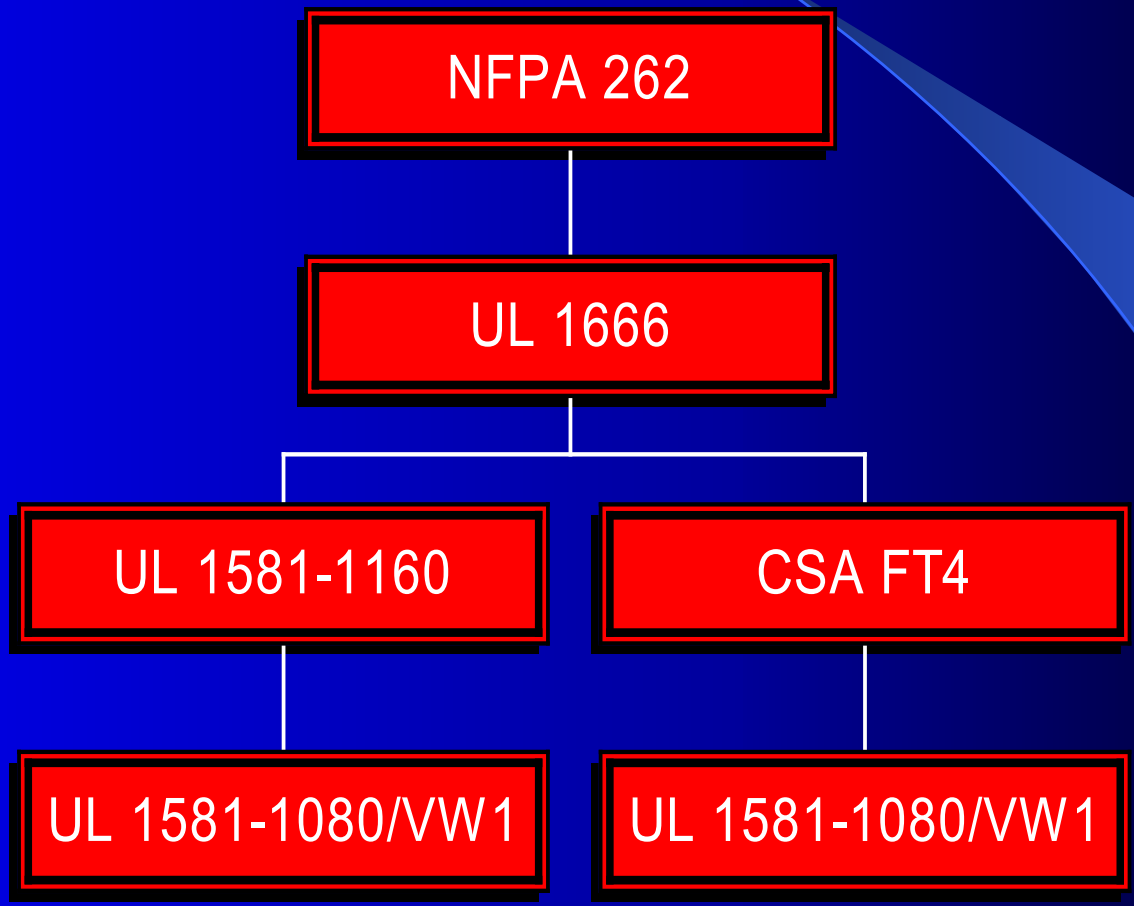
NEC Cable Fire Test Hierarchy
(in Order of Decreasing Severity)

- Best: Plenum Cables (NFPA 262)
- Riser Cables (UL 1666)
- Tray Cables (UL 1581 or CSA FT4)
- Poorest: VW 1 Cables

National Electrical Code

- Issued by NFPA as NFPA 70/NEC
- Regulates Fire Performance of Cables
- Scheme Also Used in Ships (NFPA 301)
- Scheme Proposed for Trains (NFPA 130)

NEC Cable Fire Test Hierarchy
(in Order of Decreasing Severity)



•Fire Source Input to Test

- NFPA 262: 88 kW or 300,000 BTU/hr
- UL 1666: 155 kW or 530,000 BTU/hr
- UL 1581: 20 kW or 70,000 BTU/hr
- CSA FT4: 20 kW or 70,000 BTU/hr
- VW1: 500 W

Pass/Fail Requirements: Flame

- NFPA 262: ≤ 5 feet horizontal flame spread
- UL 1666: no flame spread to second story
- UL 1581: < 8 feet vertical flame spread
- CSA FT4: ≤ 1.5 m vertical flame spread
- VW1: < 10 inches vertical flame spread

Cable Substitution

- NEC Includes Cable Substitution
- A Listed Cable for Better Test is Acceptable for a Milder Test
- Better Cables Don't Need to be Listed Again

Smoke Obscuration

- Lack of Visibility Critical to Delay Escape
- Smoke Requirements for Furnishings
- Cables are Now Major Transport Fuel Source
- Low Flame Spread Can Have High Smoke

Cable Smoke Obscuration

- Required for Some Cables in Rail/Ships
- Should be a Requirement Always
- Preferably by Testing Flame/Smoke Together

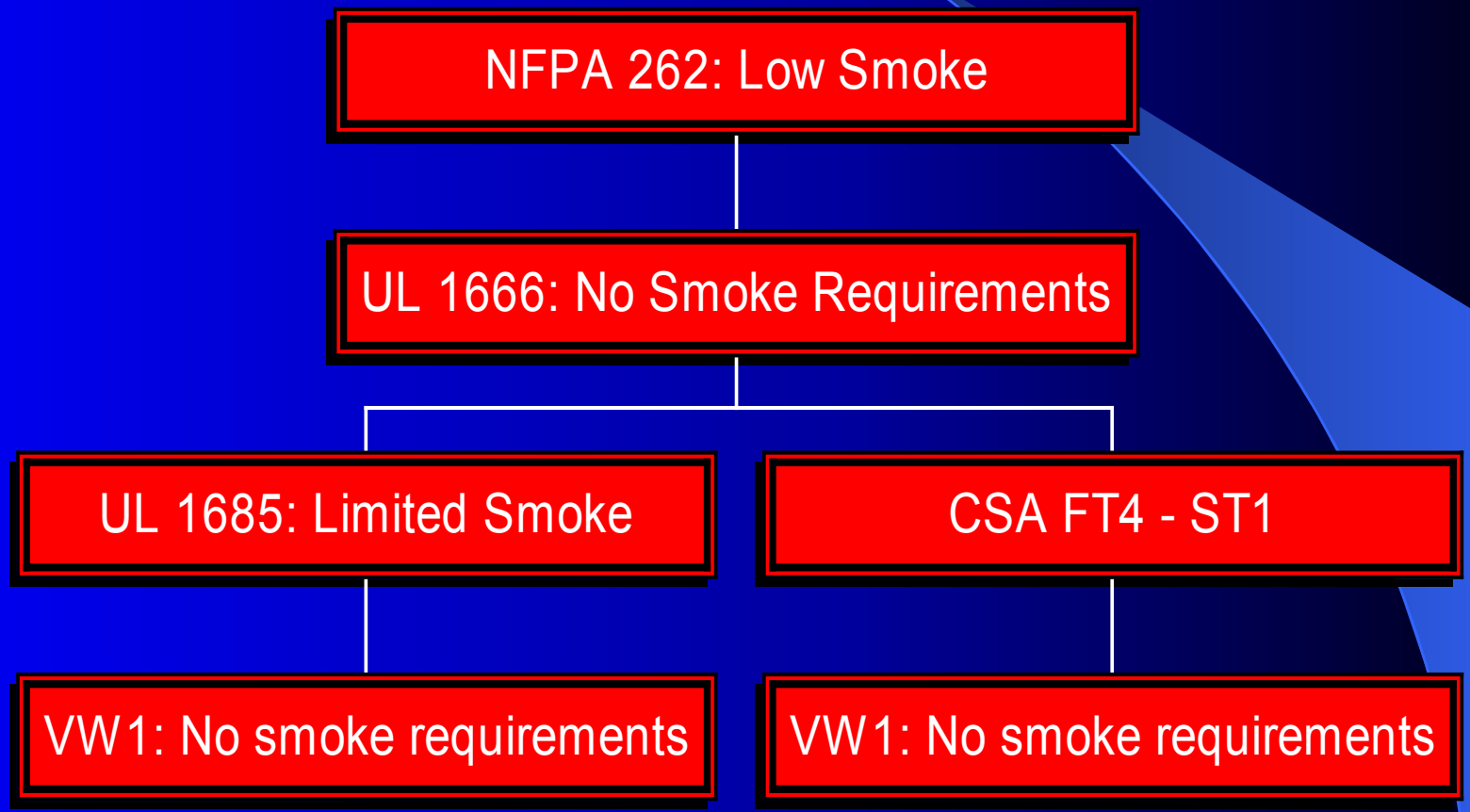
Combined Flame/Smoke Tests

- UL 1685: Listed for “Limited Smoke” (/LS)
- Two Protocols Used: “UL” and “CSA”
- NFPA 262: Steiner Tunnel Test for Cables
- Cables Listed for Plenum Use: Low Smoke

Time Available for Escape

- Smoke Obscuration Critical
- Much More Important than Smoke Toxicity
- Much Less Important than Heat Release
- Low Heat Release and Low Smoke Required

NEC Cable Smoke Test Hierarchy
(In order of Decreasing Flame Spread Severity)



Pass/Fail Requirements

- NFPA 262: ≤ 0.15 average optical density
- NFPA 262: ≤ 0.50 peak optical density
- UL 1685: ≤ 0.25 m^2/s peak smoke release rate
- UL 1685: ≤ 95 m^2 total smoke released
- CSA FT4: ≤ 0.92 m^2/s peak smoke release rate
- CSA FT4: ≤ 345 m^2 total smoke released

Small Scale Heat Release Cable Tests: for Hazard

- OSU Calorimeter: FAA – ASTM E 906
- Cone Calorimeter: ASTM E 1354
- FM Calorimeter – ASTM E 2058

Cone Calorimeter

Cone Calorimeter

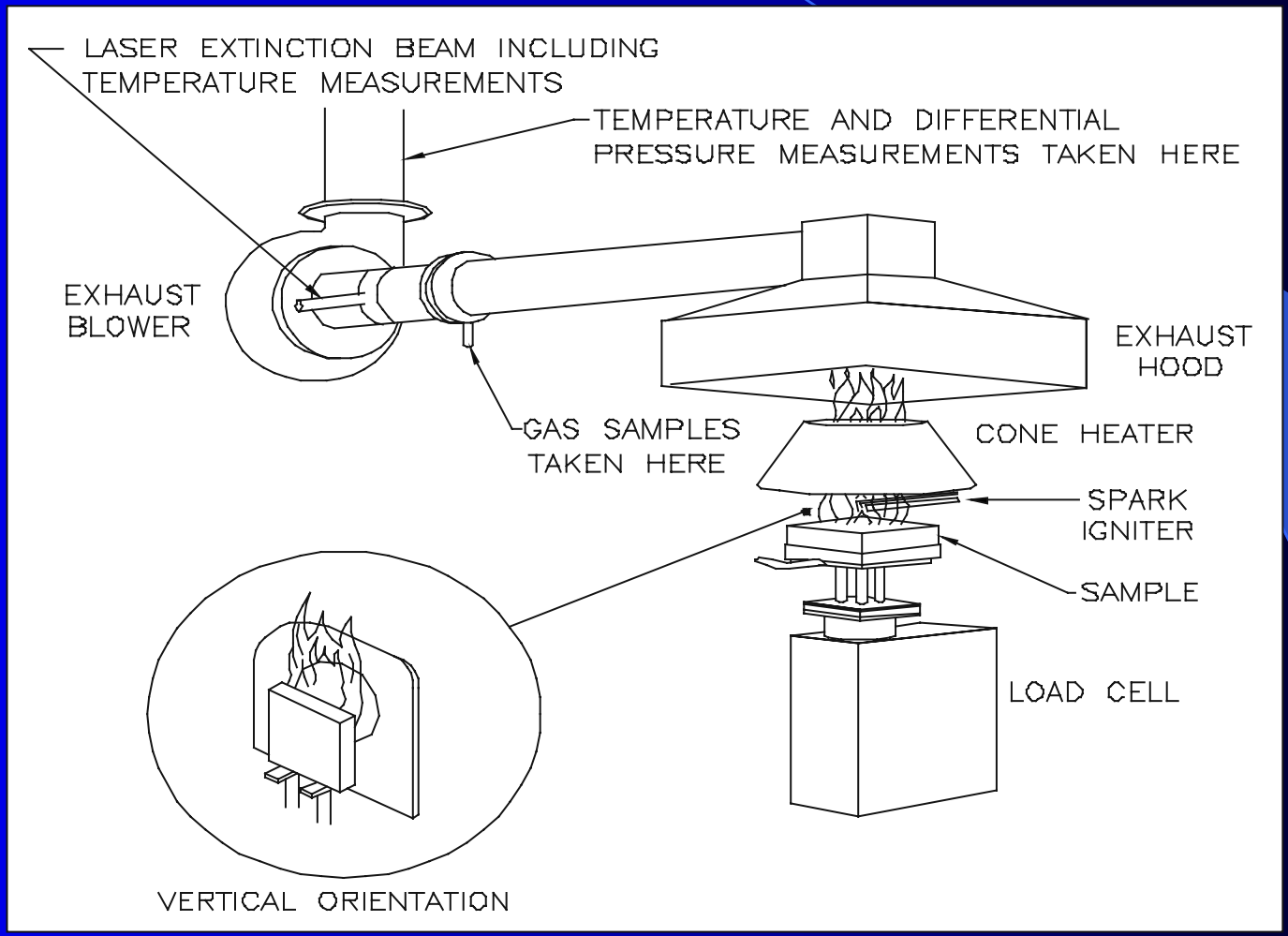
- Advanced Version of OSU Calorimeter
- Predicts Vertical Cable Tray Tests
- Predicts Full Scale Cable Results
- Used Extensively for All Materials

Cone Calorimeter: Small Scale Research and Prediction Test

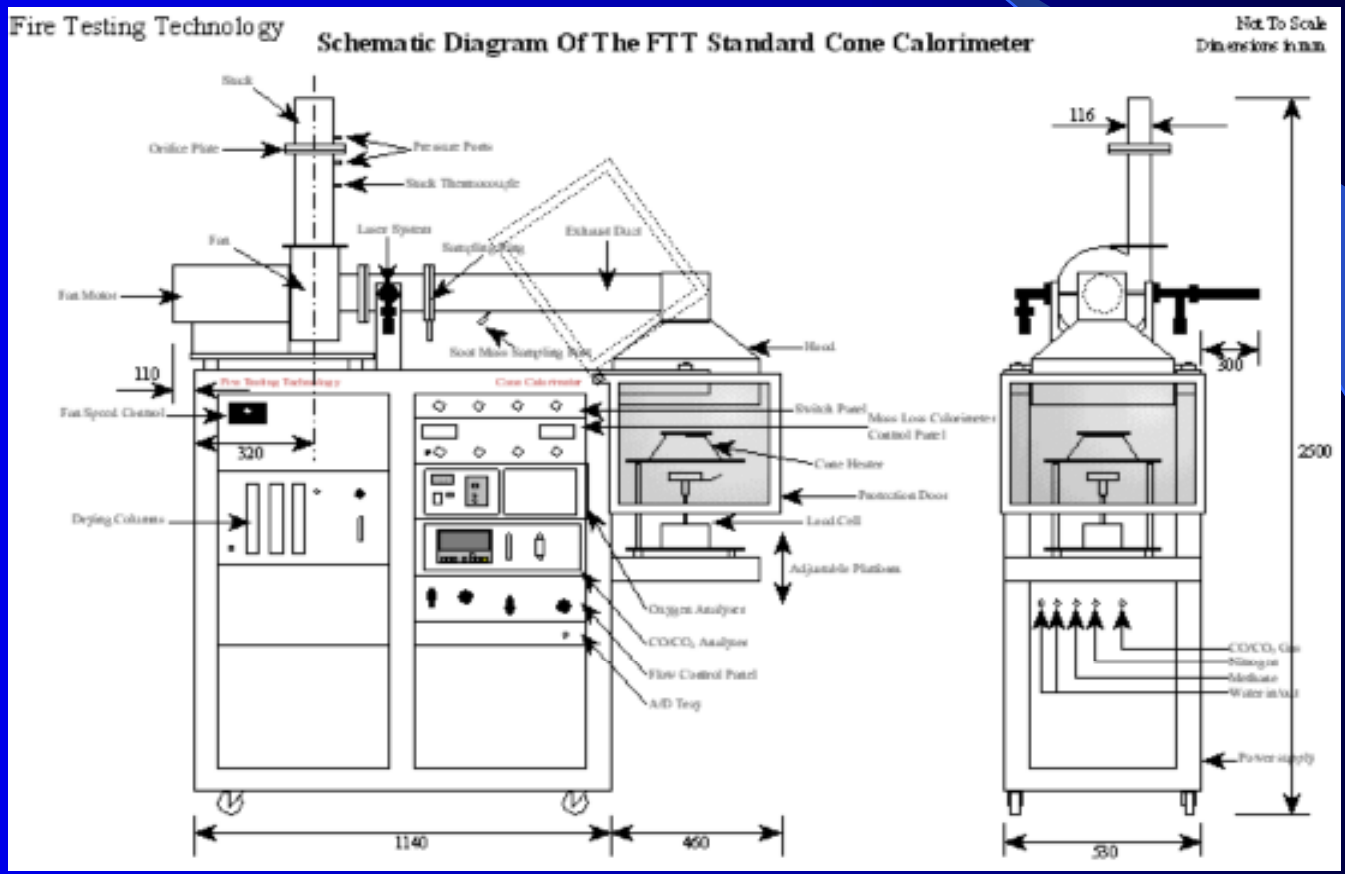
- Basic Standard: ASTM E 1354/ISO 5660
- Application to Cables: ASTM D 6113
- IEC and CENELEC Drafts Exist Also of Application Standard

Photograph of Cone Calorimeter

Schematic of Cone Calorimeter in Concept



Detailed Schematic of Sections of Cone Calorimeter



What Does the Cone Calorimeter Do?

The cone calorimeter measures:

- Heat release rate
- Total heat released
- Effective heat of combustion

(all measurements done by the oxygen consumption principle)

What Does the Cone Calorimeter Do?

The calorimeter also measures:

- Mass loss rate
- Time to ignition
- Specific extinction area (i.e. smoke), and
- Optionally, CO/CO_2 production

Cone Calorimeter

Sample Exposure:

- **Radiant heat fluxes from a conical heater**
- **Exposure ranges from 0 to 100 kW/m^2**
- **Horizontal Orientation**

Why Measure Heat Release?

Heat Release is the Most Critical Fire Property:

- It is an indication of the intensity of the fire
- It governs the progress of the fire
- It is relatively easy to extrapolate to a larger scale
- It can be used for predictions of fire performance

Oxygen Consumption Principle

The amount of heat generated per unit mass of oxygen consumed has been shown to be almost independent of the material burning, it is usually very close to 13.1 MJ of energy per kg of oxygen consumed, for normal combustible materials

Cone Calorimeter Measurement Concept

It is not necessary to capture all the heat emitted but simply to ensure that all the smoke and gases released are assessed

Cone Calorimeter

- Used in Rail Rulemaking as Alternate Test
- Useful for Fire Hazard Analysis
- Used Extensively by NIST and FAA and Others
- Can be Used for Fire Modeling
- Not Suggested for Regulation

Ships

Ships: NFPA 301 – 2001

- Flame Propagation Test: IEEE 1202
- For All Cables: Power & Data
- Cable Substitution Permitted
- Smoke Obscuration Optional

Trains

Rail: NFPA 130 – 2000

- Flame Propagation Test: IEEE 383
- Within Vehicles, Power Cables Only
- Must Also Meet Circuit Integrity
- No Circuit Integrity in IEEE 383

Rail: NFPA 130 – 2000

- Flame Propagation Test: IEEE 383
- Power and Control Cables, within:
- Stations – Trainways
- Emergency Ventilation Systems

Rail: NFPA 130 – 2000

- Insulation for Control & Low Voltage Cables

  In Vehicles

- Must Meet UL 1581 VW-1 Flame Test

FRA Rulemaking 5/12/1999

- Flame Propagation Test: IEEE 383-1974
- Power Cables in Vehicles
- UL 1581 VW 1, as per UL 44 or UL 83
- Low Voltage Cables in Vehicles

FRA Rulemaking 5/12/1999

- UL 44 and UL 83 More than a Fire Test
- VW 1 Test Better Described in UL 1581

FRA Rulemaking 5/12/1999

- Cables Not Discussed Explicitly:
- Data/Communications Cables
- Fire Alarm Cables
- Optical Fiber Cables: Missing Totally

FRA Rulemaking 5/12/1999

- Smoke: ASTM E 662 (NBS Chamber)
- Only for Power Cables in Vehicles
- Low Voltage Cables in Vehicles
- $D_s < 200$ (F) - $D_s < 75$ (NF)

Suggested Rail Cable Scheme

- UL 1581-1160 required for all cables
- NEC Substitution Scheme Permitted

- Listed Cables Need not be Retested
- Provided Listed for Better Flame

- CSA FT4 – Riser – Plenum: Allowed

Comparison with Ships: NFPA 301

- Same NEC Substitutions Permitted
- Less Severe Minimum Test: UL vs. CSA
- Easier to Escape from Trains than from Ships or Aircraft

Suggested Rail Cable Scheme

- Smoke Always Required for Cables
- UL 1685 Limited Smoke or ASTM E 662
- Substitution Permitted: Riser & Either Limited Smoke or ASTM E 662
- Substitution Permitted: Plenum

Aircraft

Aircraft Cable Tests

- Concealed Spaces are Being Investigated
- Issue is Ensuring No Flame Spread
- Fire Source is Probably Small
- Initial Suggestion: Modified ASTM E 648

All Public Transportation

Optical Fiber Cables

- Many Data/Communications Cables
- Improved Data Transmission
- As Much Fuel As Electric Cables
- Lacks Metallic Conductor Heat Sink

Conclusions (1)

- Cables are Increasing Transport Fuel Source
- Fire Tests Requirements Obsolete Aircraft/Rail
- Smoke Requirements Missing & Needed
- Modeling Provisions Missing
- Optical Fiber Cables: Missing

Conclusions (2)

- Cables are Critical in All Vehicles
- Flame: Cable Tray Minimal Requirement
- Cable Substitution Needed, per NEC
- Smoke Requirement for All Cables
- Optical Fiber Cables: Same as Electrical

Conclusions (3)

- Optional Provisions Should be Included for Fire Hazard Analysis Considerations
- Heat Release Tests can Help for That Purpose
- Small Scale Tests Not Suitable for Regulation
- Cone Calorimeter Useful Tool for Modeling