Fire Endurance Testing * of WTC Tower Typical Floor Construction

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- Test results will provide fire endurance ratings to evaluate three primary factors
  - test scale
  - fireproofing thickness
  - thermal restraint

* ASTM E119 - Standard Test Methods for Fire Tests of Building Construction and Materials

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Fire Endurance Testing of WTC Tower Typical Floor Construction

- Three tests will be performed…
  - 17 ft (5.2 m) span assembly, thermally restrained
  - 35 ft (10.7 m) span assembly, thermally restrained
  - 35 ft (10.7 m) span assembly, thermally unrestrained

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Fire Endurance Tests

- **Test 1: 17 ft (5.2 m) span assembly, thermally restrained**
  - Represents current US practice for establishing a fire endurance rating of a building construction.
  - Typical of the floor assembly test furnaces used by the US testing laboratories that routinely conduct the ASTM E119 test.

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Fire Endurance Tests

- **Test 2: 35 ft (10.7 m) span assembly, thermally restrained**
  - Twice the scale of the first test. Represents a full-scale assembly of a 35 ft floor panel.
  - Allows direct comparison to Test 1 of the effect of test scale on fire endurance rating.
  - Includes individual rod and double angle structural members. Steel temperatures will be recorded for comparison of fireproofing thickness and the limiting criteria.

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Fire Endurance Tests

- **Test 3: 35 ft (10.7 m) span assembly, thermally unrestrained**
  - Allows direct comparison to Test 2 of the effect of thermal restraint on fire endurance rating.
  - Tests 2 and 3 will bound behavior of a floor system that is indeterminately restrained.

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ASTM E119
Standard Test Methods for Fire Tests of Building Construction and Materials

- ASTM E119 prescribes a standard exposing fire of controlled extent and severity
- Performance is defined as the period of resistance to standard exposure before the first critical point in behavior (conditions of acceptance or end point conditions) is observed.
- Conditions of acceptance include (for floor systems)
  - Sustained applied load during classification period
  - Maximum temperature on unexposed side of the specimen
  - Maximum and average temperatures of the steel joists

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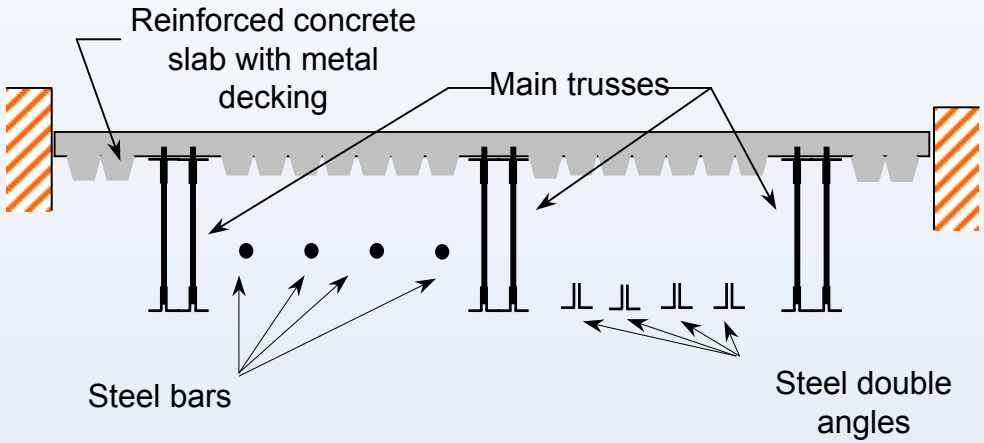
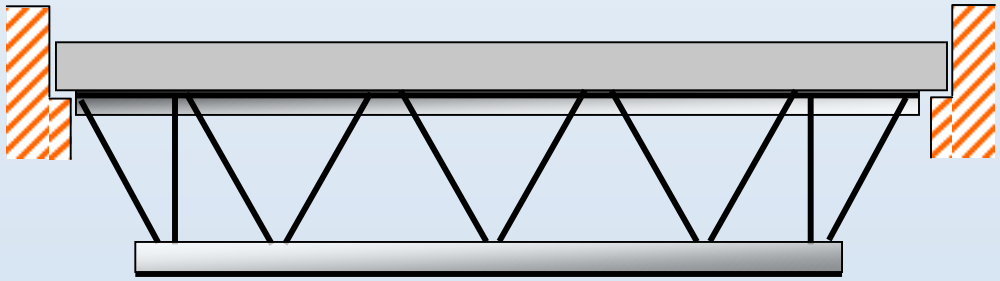
Elevations of Test Configuration

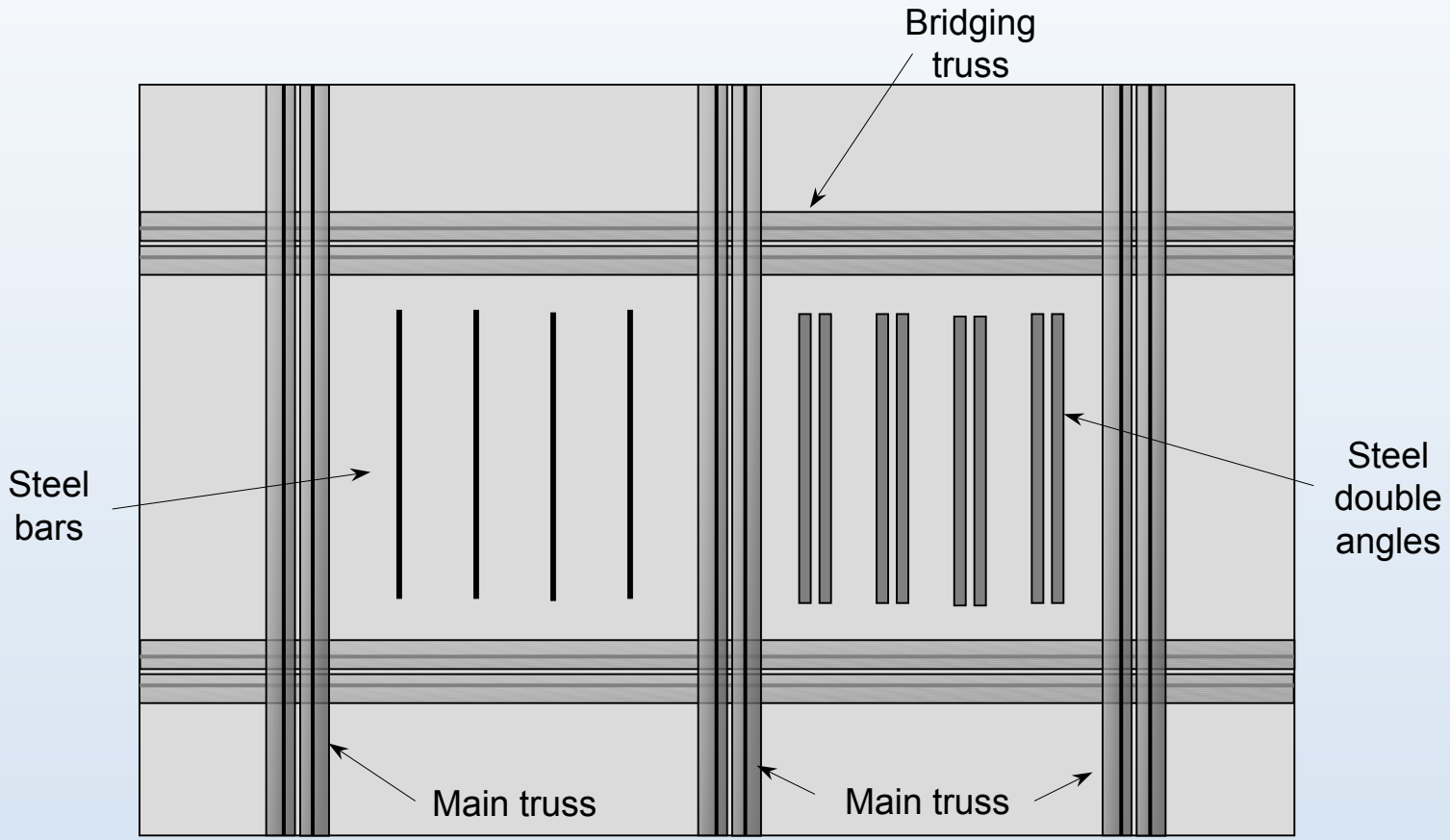


END VIEW
(Note: Bridging trusses are not shown for clarity)



SIDE VIEW
(Note: Bridging trusses are not shown for clarity)

Plan View of Test Configuration



Instrumentation

- **Temperature Measurements** (exceed ASTM E119 requirements)
  - Measurement of the temperature of the steel along the length of the members
  - Measurement of the temperature of the unexposed surface (top) of the concrete slab
  - Measurement of the temperature of the bottom of the concrete slab (steel deck)

- **Deflection** (not required by ASTM E119)
  - Deflection measurements will be made at 9 locations on the unexposed side of the specimen as well as at mid-span on the bottom chord of both main trusses

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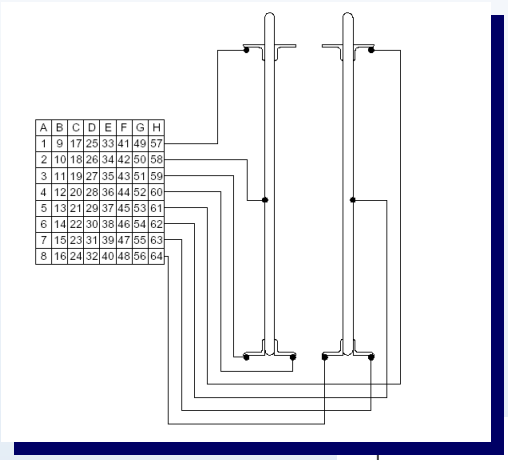
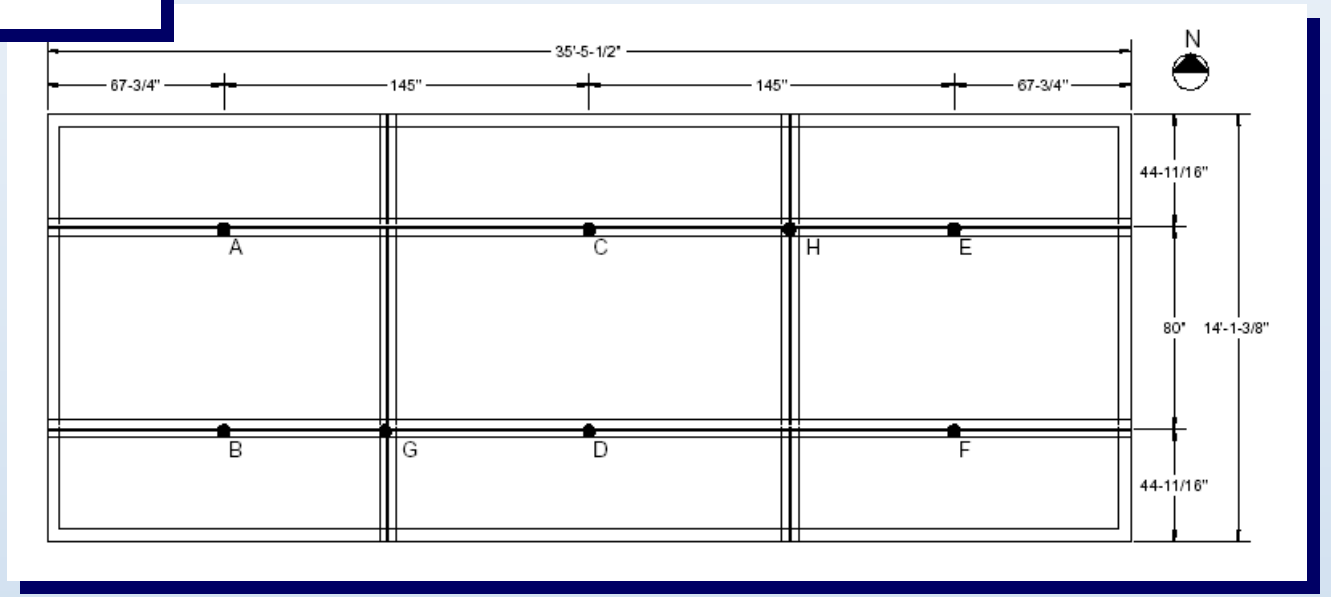
Instrumentation (Cont'd)

- **Gas Temperatures** (not required by ASTM E119)
  - Gas temperatures will be continuously recorded at three locations using plate thermometer and aspiration thermocouples

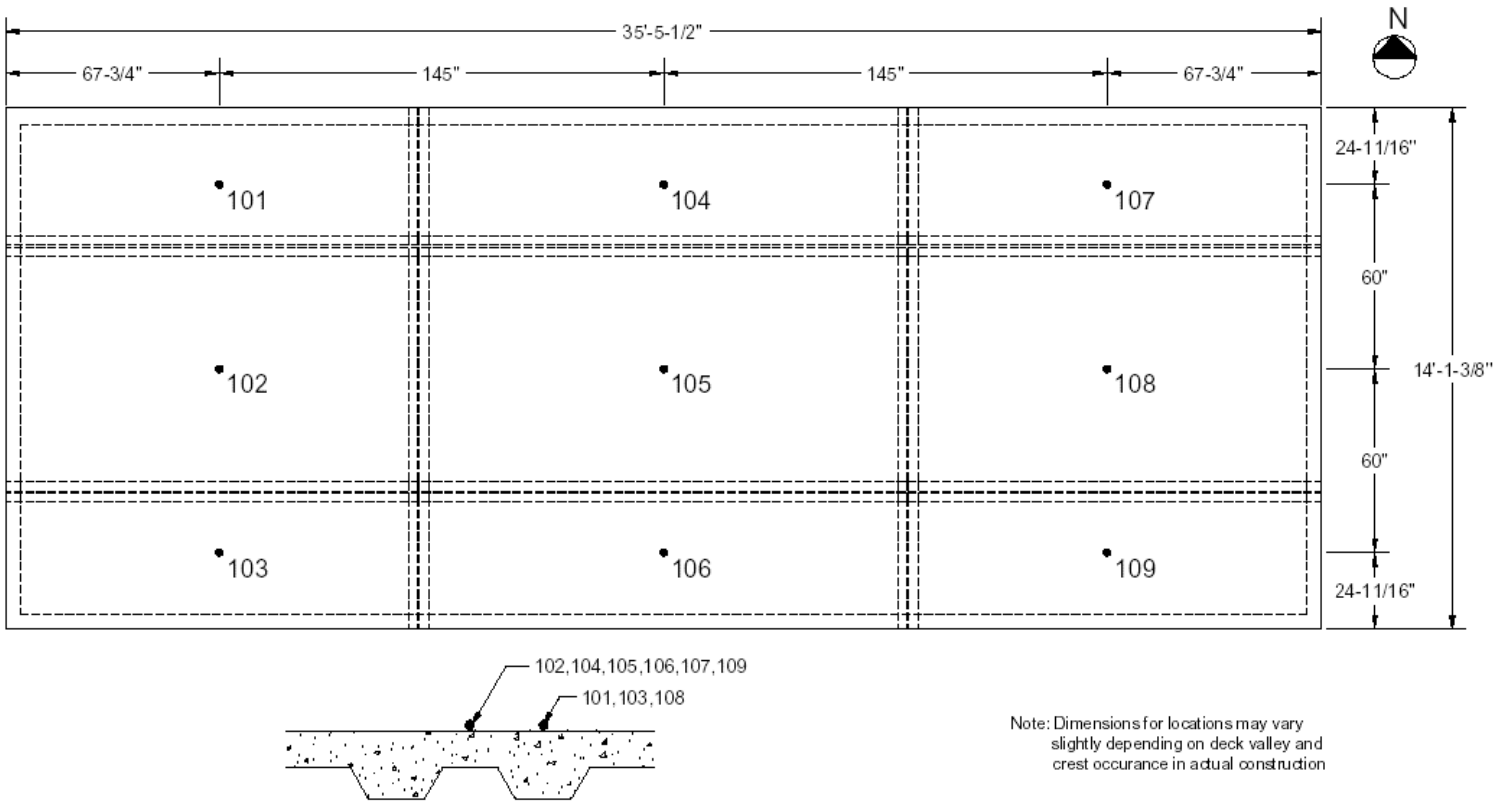
- **Heat Flux** (not required by ASTM E119)
  - Radiative heat flux will be measured at lower surface of metal deck and to the bottom flange of the main trusses using wide-angle radiometers

Thermocouples on Main Trusses





Thermocouples on Unexposed Surface of Concrete Slab



ASTM E119 Conditions of Acceptance (or end point criteria)*

- Transmission of heat through the specimen shall not have been such as to raise the average temperature on its unexposed surface more than 250 ºF (139 ºC) above its initial temperature.
- The temperature of the steel shall not have exceeded 1300 ºF (704 ºC) at any location
- The average temperature of the steel recorded by four thermocouples at any section shall not have exceeded 1100 ºF (593 ºC)

* Tests will be conducted until specimen fails to sustain the applied load (without damaging the furnace)

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Schedule for Testing

- Start – “Kick-off” meeting with Contractor held August 18, 2003
- Testing – approximately 9 months
- Results – shortly thereafter

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May 2003 Progress Report: Fire Protection
(Page 74)

- In October 1969, … , the Port Authority stated, in a letter to the fireproofing contractor, that
  - "All Tower beams, spandrels, and bar joists requiring spray-on fireproofing are to have a ½" [**1/2 in**] covering of Cafco.
  - The above requirements must be adhered to in order to maintain the Class 1-A Fire Rating of the New York City Building Code."[1]

[1] Letter dated October 30, 1969 from Robert J. Linn (Manager, Project Planning, The World Trade Center) to Mr. Louis DiBono (Mario & DiBono Plastering Co., Inc.).

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May 2003 Progress Report: Fire Protection
(Page 80)

- In 1999, the Port Authority established “guidelines regarding fireproofing repairs, replacement, and upgrades” for the towers. The guidelines for tenant spaces may be summarized as follows:
  - For full floors undergoing new construction or renovation, the bar joists should be fireproofed with 1-1/2 in of spray-on mineral fiber fireproofing. Refireproofing requires removal of existing material and controlled inspection.
  - For “tenant spaces less than a full floor undergoing new construction or renovation,” the floor trusses “need only meet the original construction standard. Fireproofing shall be inspected and patched as required to the greater of **3/4 in** or to match existing” if it has already been upgraded to 1-1/2 in.

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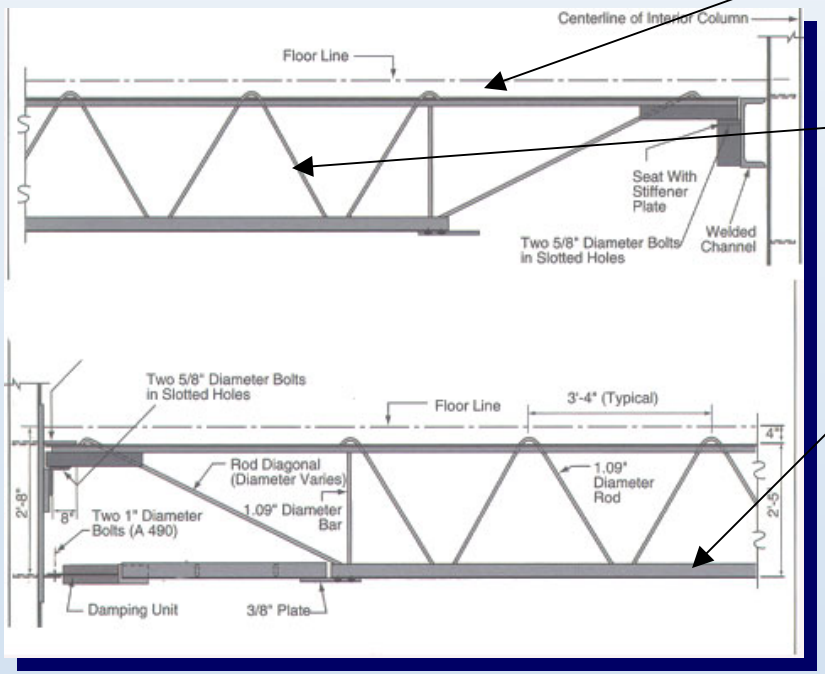
Truss Specified Mechanical Properties

About 50 truss variants (60', 35', bridging trusses, 20+ variants per length



Top Chord
A242
Typically 2.5" x 1.5" x 0.25"

Web
A36 (60' truss) (1.09" round)
A242 (35' truss) (0.98" round typ)

Bottom Chord
A36
Typically 3" x 2" x 0.37"

ASTM Specifications

A36: Yield Point = 36ksi
A242-70 type 2: Yield Point = 50 ksi

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As-Built Properties

- Truss components typically meet contemporaneous specification. A36 components far exceed minimums.
- No obvious differences (chemistry/microstructure/mechanical) between steel specified as A36 and that specified as A242
- Truss steel would meet (chemistry and yield strength) present-day A572 (Type 2 or Type 4) Grade 50 steel

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Selection of Key Test Parameters

- Fireproofing Thickness
- Steel Specification

Should the planned tests address the fire endurance rating of …

- what was originally specified for the design?
  - 0.5 in of fireproofing per letter to DiBono
  - minimum steel strength (36 ksi; 50 ksi)

- as-built conditions at time of collapse?
  - 0.75 in of fireproofing per measurements
  - Supplied steel strength (over 55 ksi)

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If test is for …

Specified Conditions

- Will provide design information not available in the early 1960s
- Will establish minimum performance expectation for specified system

As-built Conditions

- Will provide as-built information for investigative purposes
- Will establish data on performance of as-built system at time of collapse

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Other Considerations…

- Steel primer paint

  Should the planned tests have primed or unprimed steel?

  - WTC steel was primed
  - Testing Laboratories generally require that steel not be primed or require the use of specific primers

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