

Structural Fire Safety in the US: Basic Issues and Future Trends

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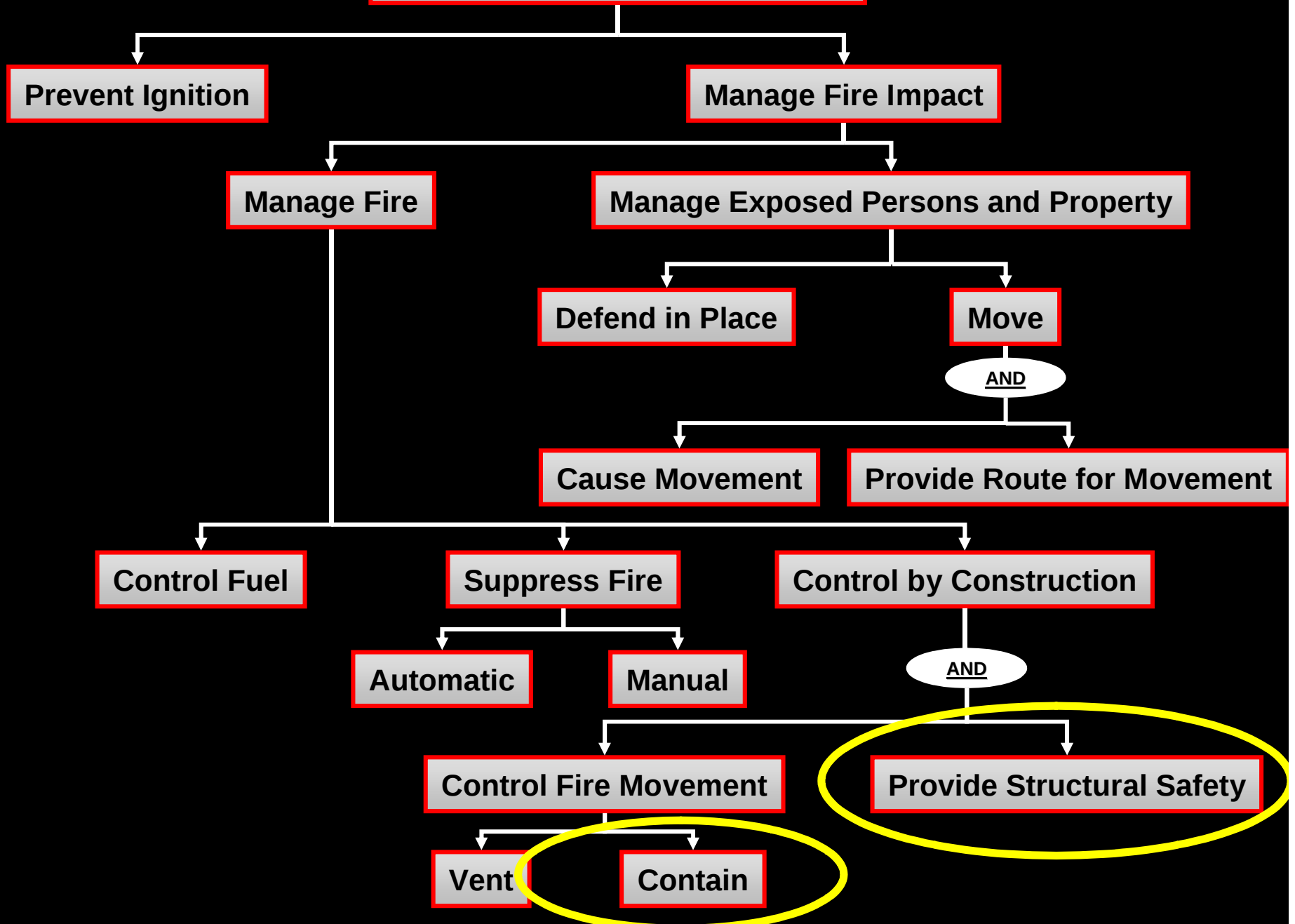
Fires in the US: Typical Annual Statistics

- 3800 Fatalities
- 20,000 Injuries
- 100 Firefighters killed on duty
- 80 percent of civilian fire deaths occurred in residences
- 1.6 million reported fires (including 35,000 intentionally set structure fires)
- Structure fire every 60 seconds

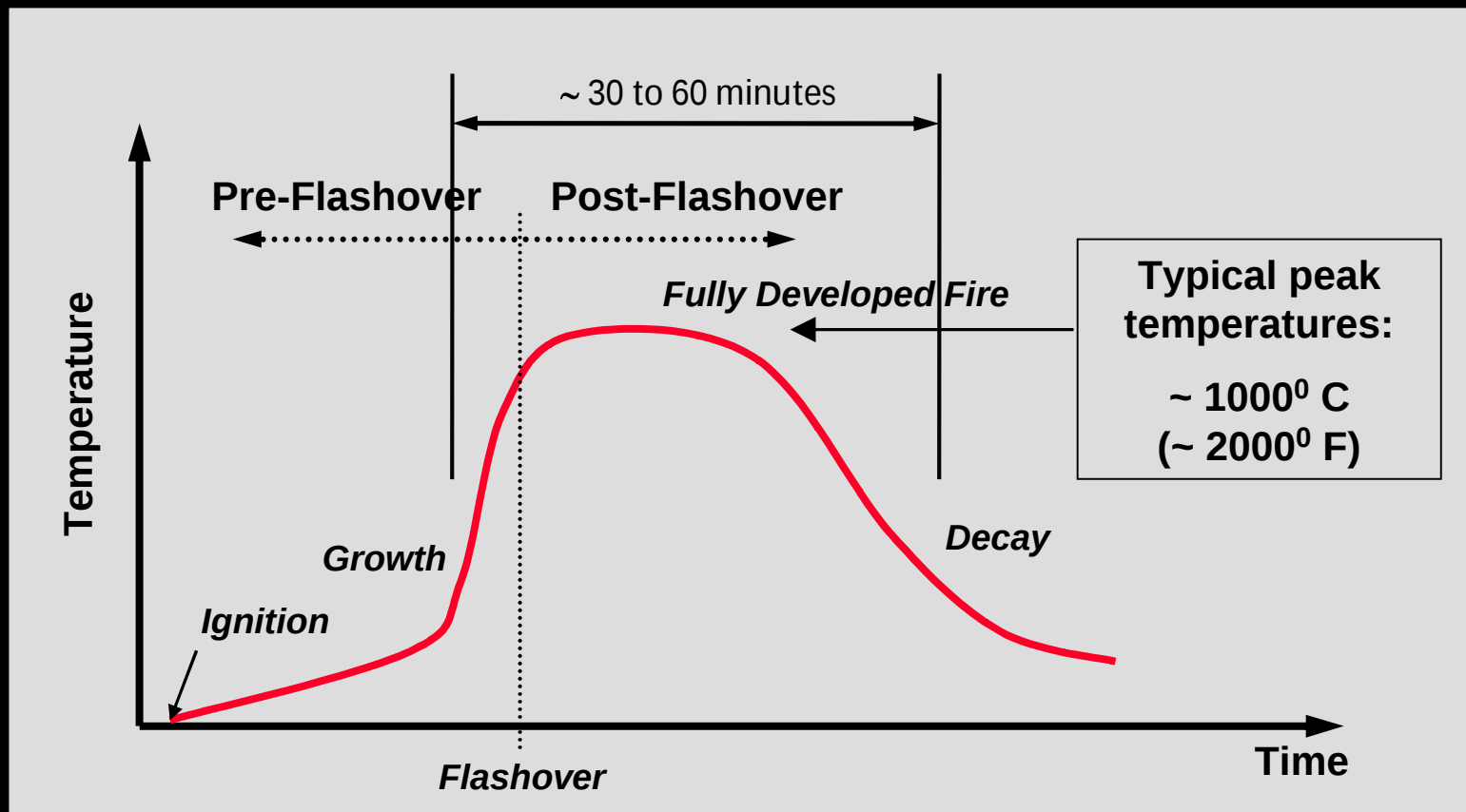
The Cost of Fire in the US

- Total annual cost: *\$250 Billion*
(2.5-percent of US GDP)
- 12-percent of cost of non-residential buildings
for fire protection
- Cost of building fire protection has increased
by 55-percent since 1980 (after adjusting for
inflation)

Fire Safety Strategies (NFPA)



Typical room fire.....



Structure Fires

- Residential structures
- Small buildings
- Major buildings
- Some special cases

Residential Structures.....



Small Buildings.....







Major Buildings.....

Interstate Bank Building

Los Angeles

62 stories

Fire: May 1988

Fire burned 4 hours

Destroyed Four Floors
No Collapse

\$50 Million damage



One Meridian Plaza

Philadelphia

38 stories

Fire: February 1991

Fire burned 19 hours over 8 stories

Interior fire fighting operations halted after 11 hours due to concerns for structural collapse

Building demolished





Textile Factory

Alexandria, Egypt

6 stories

Fire: July 2000

Nine hours after start of fire: Building collapsed

27 fatalities

Parque Central East Tower

Caracas, Venezuela

56 stories

Fire: October 2004

Fire burned 24 hours over 17 stories

100 fire fighters inside building.

Interior fire fighting operations halted
after 12 hours due to concerns of
structural collapse.



Windsor Building

Madrid, Spain

32 stories

Fire: February 2005

Fire burned approx. 24 hours

Large portions of upper stories
collapsed

Building was demolished
shortly after the fire





Some Special Cases.....

Fires in 1995 Kobe Earthquake

780 deaths resulting from fire

7200 buildings - complete
burnout



World Trade Center Collapses
September 11, 2001



World Trade Center Building 7

47 stories

No aircraft impact

**Fires apparently ignited by
debris from WTC1 collapse at
10:30 am**

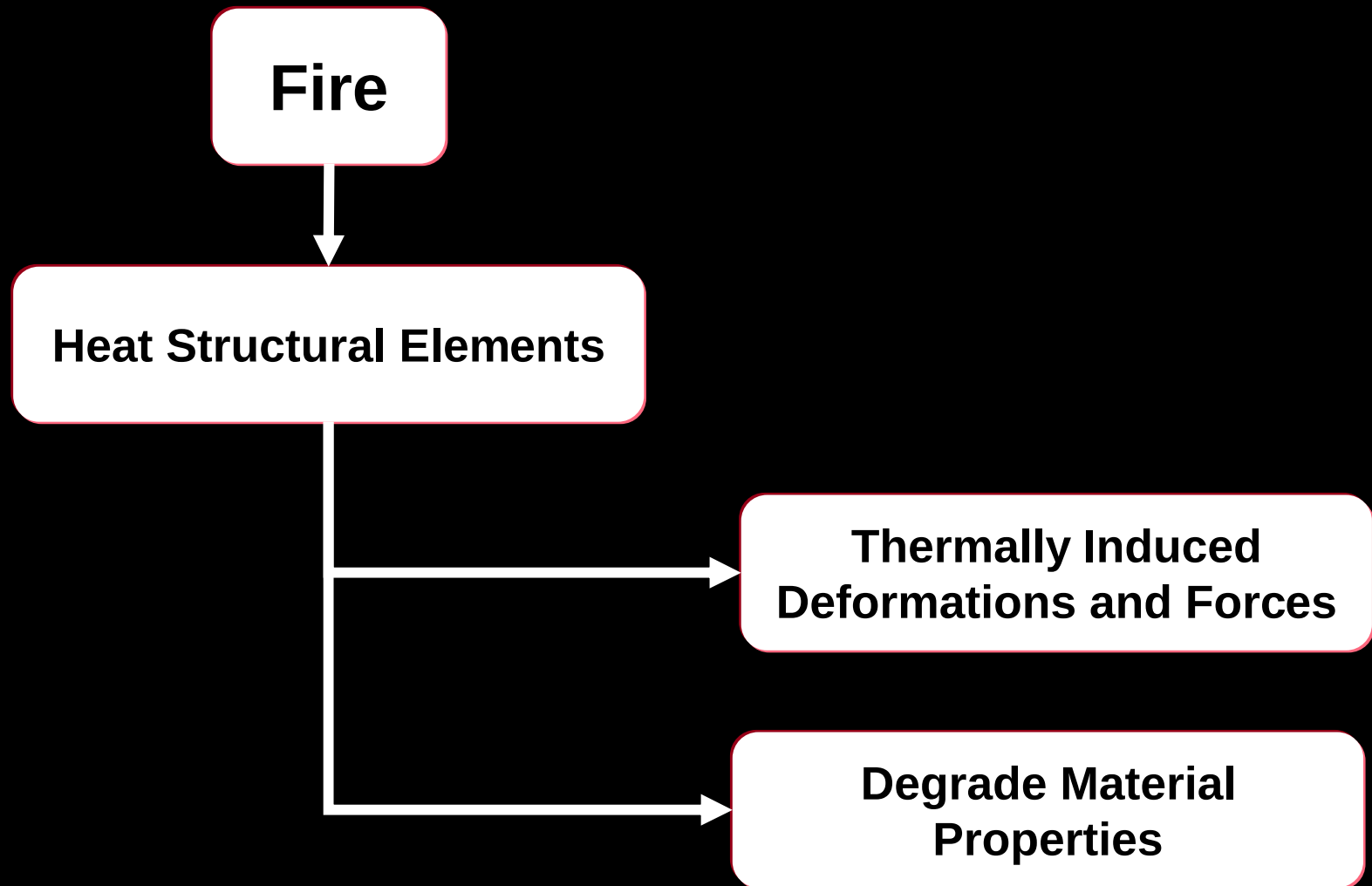
**Building burned 7 hours
(no fire fighter intervention)**

**Building completely collapsed
at 5:24pm**



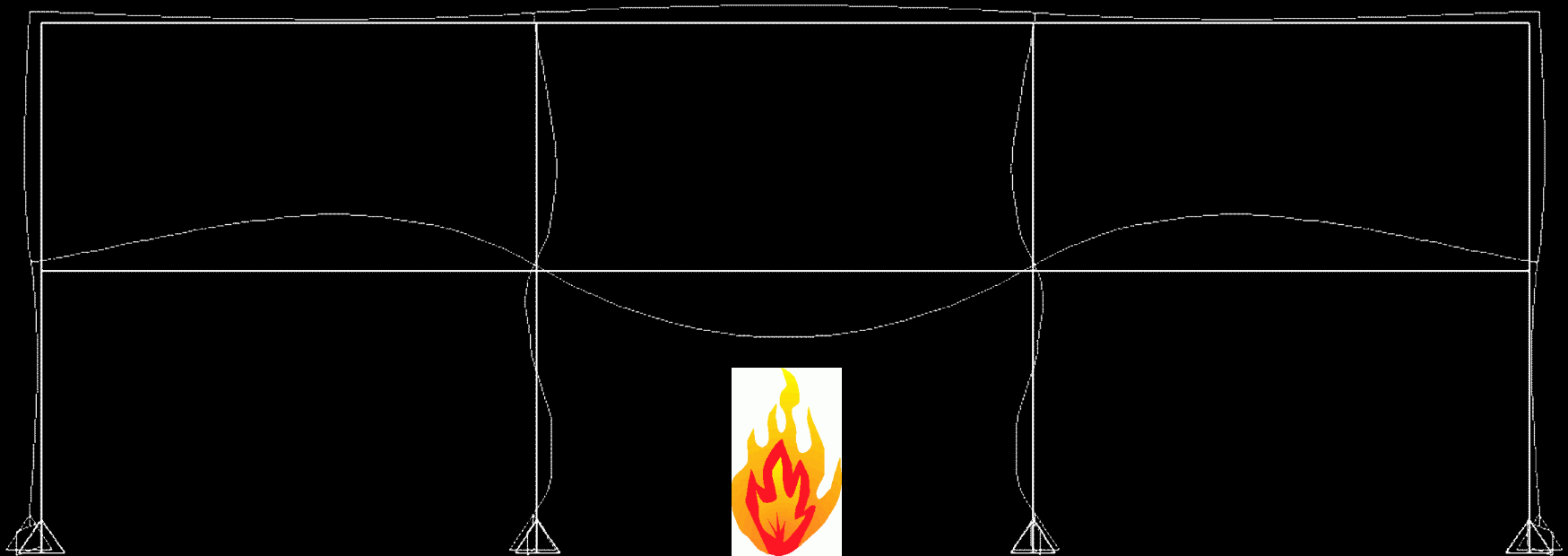


Fire Effects on Structures



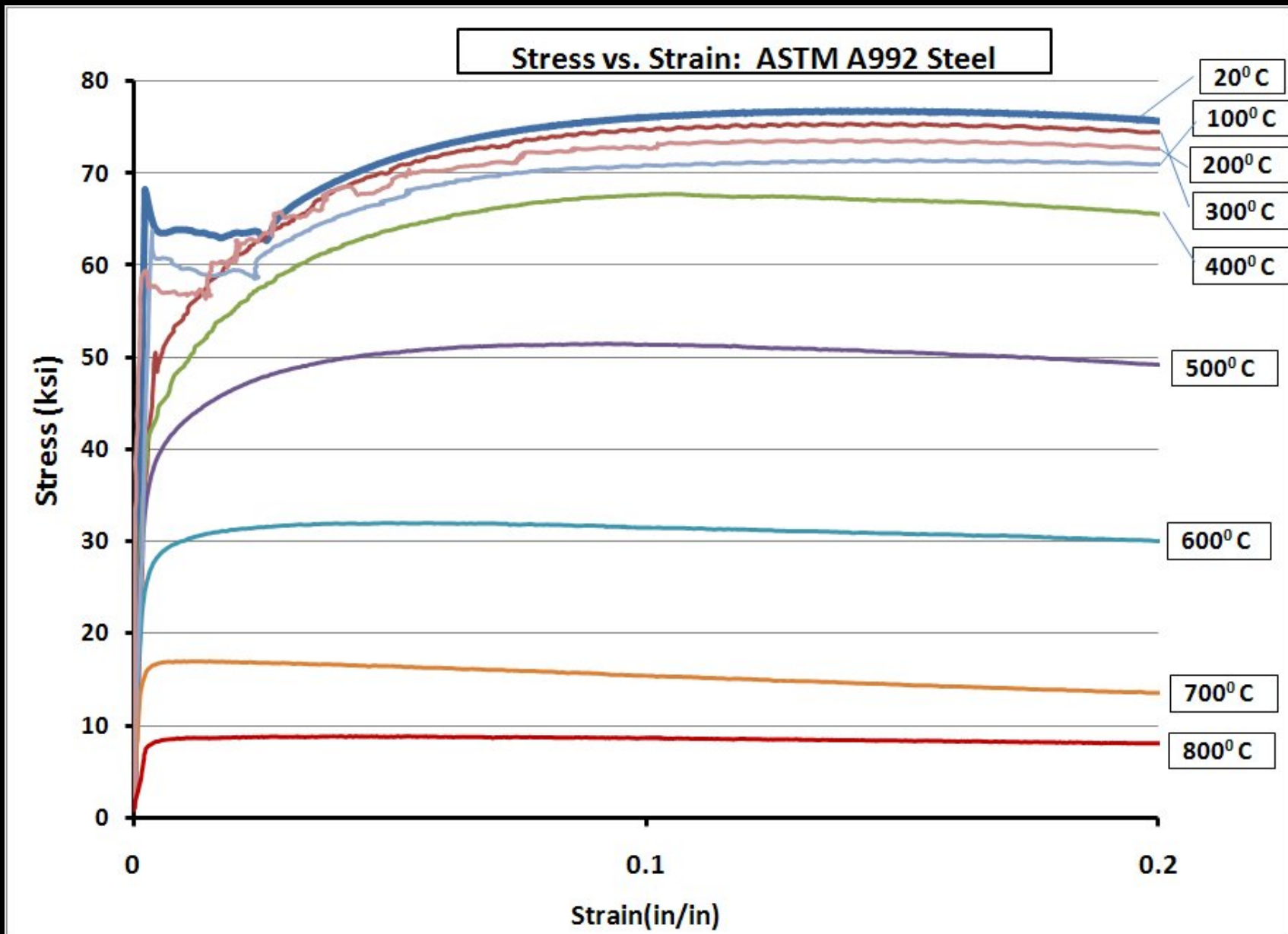
Typical Thermal Properties

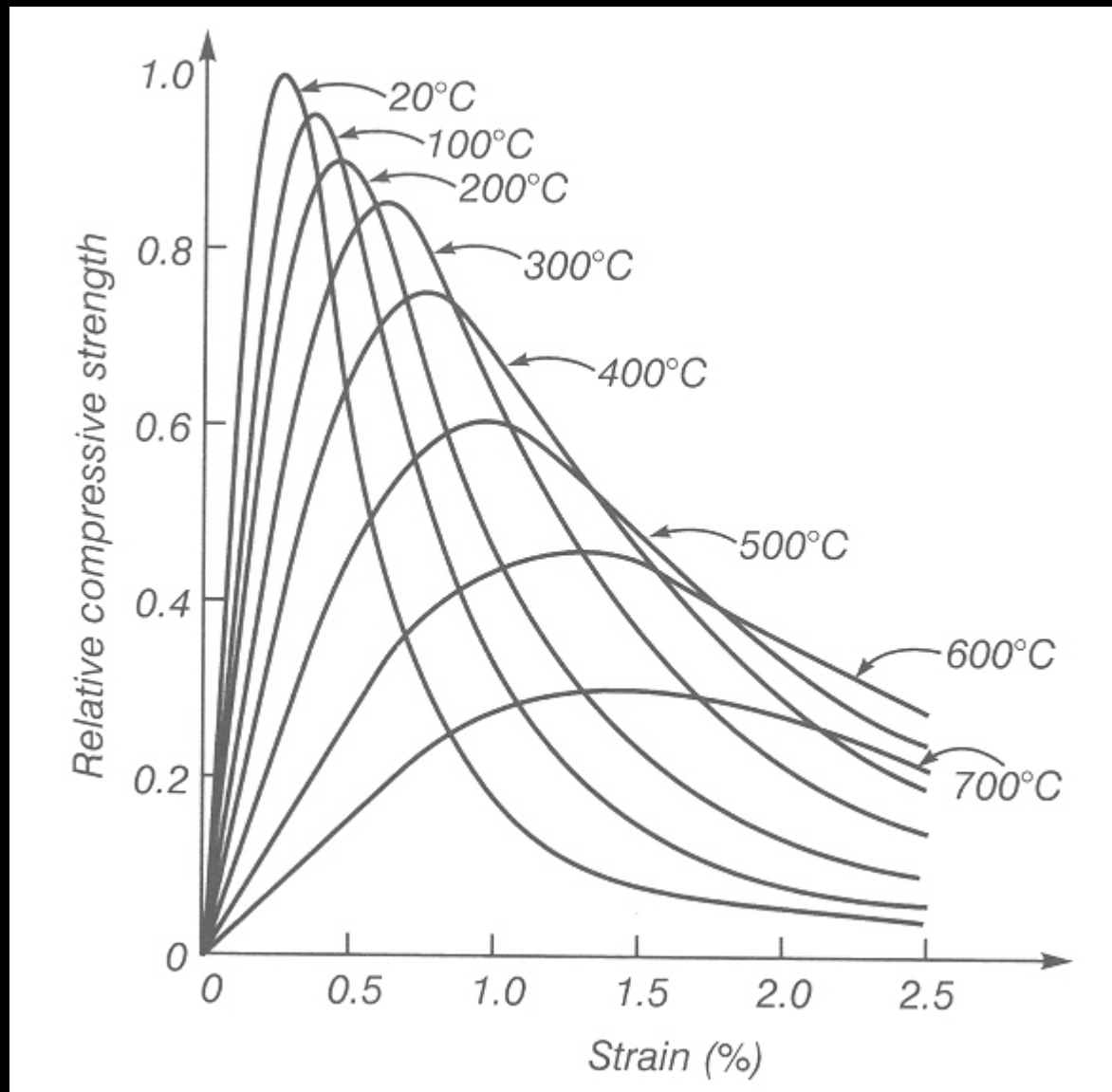
	Thermal Conductivity (W / m K)
Steel	46
Concrete	1.0
Yellow Pine	0.15



Thermally Induced Deformations and Forces

Material Degradation at Elevated Temperatures.....





Concrete

Typical Current US Practice for Structural Fire Safety

Some key points.....

- Structural fire protection is highly regulated by Building Codes and Standards
- Overall approach: Prescriptive
- Primary unit for assessing structural fire resistance: *Hours*
- Involvement by Structural Engineer.....
Little or None

Typical Current US Practice for Structural Fire Safety

- Building Code specifies required fire resistance rating of building elements, based on type of construction, building size and occupancy.

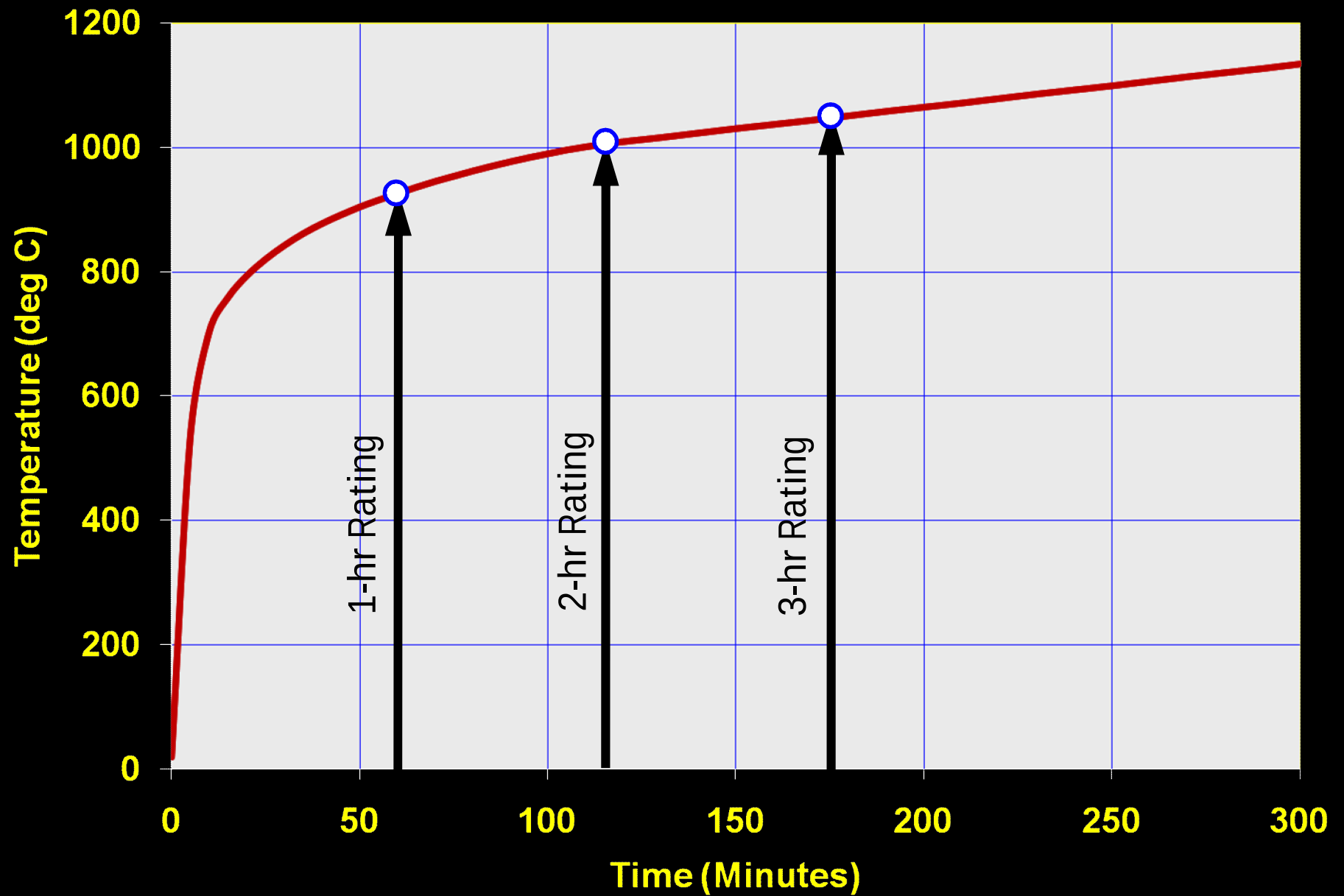
Example:

- Structural Frames (columns and directly connected girders):
 3 hour rating required
- Floor Construction:
 2 hour rating required
- Fire resistance (hourly) rating determined by testing in accordance with:

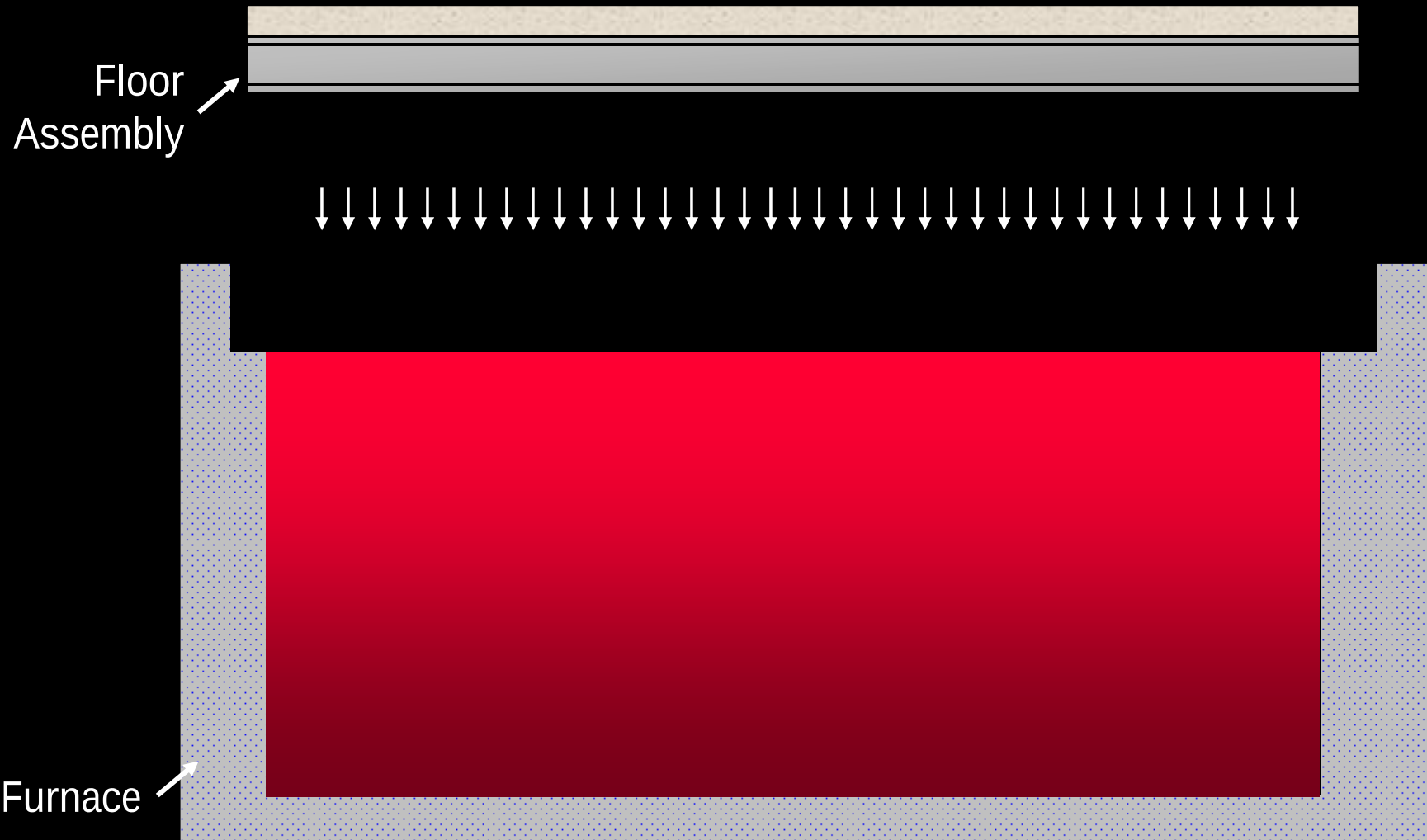
ASTM E119

"Standard Test Methods for Fire Tests of Building Construction and Materials"

ASTM E 119 Time-Temperature Curve



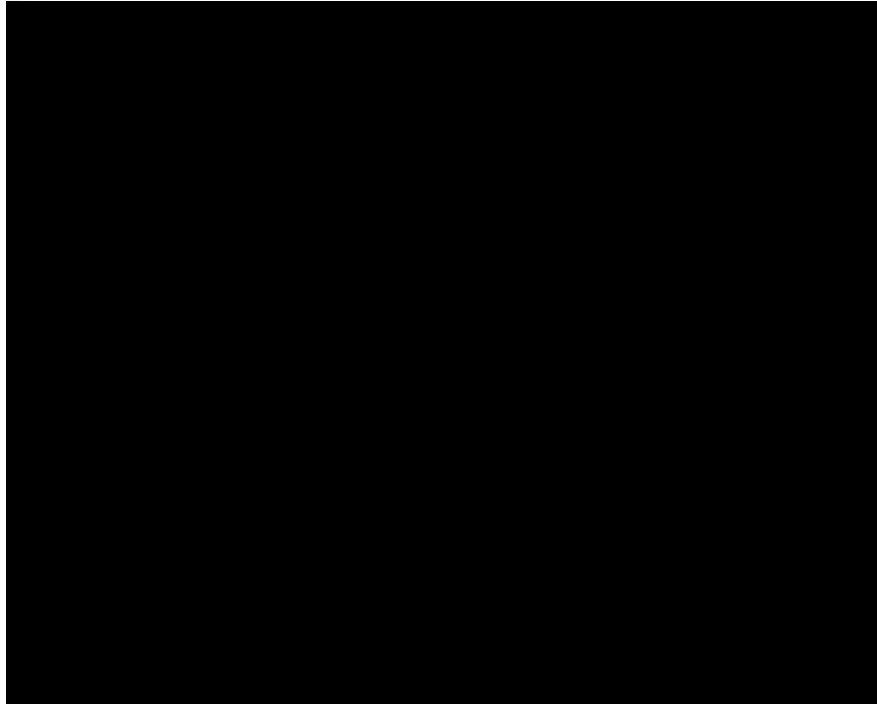
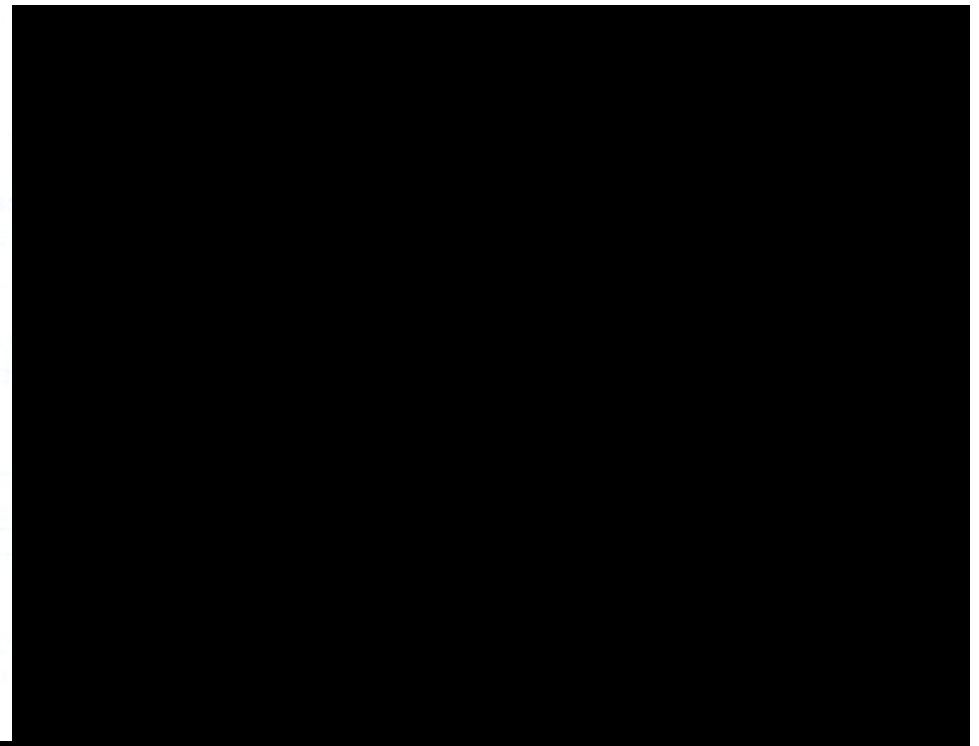
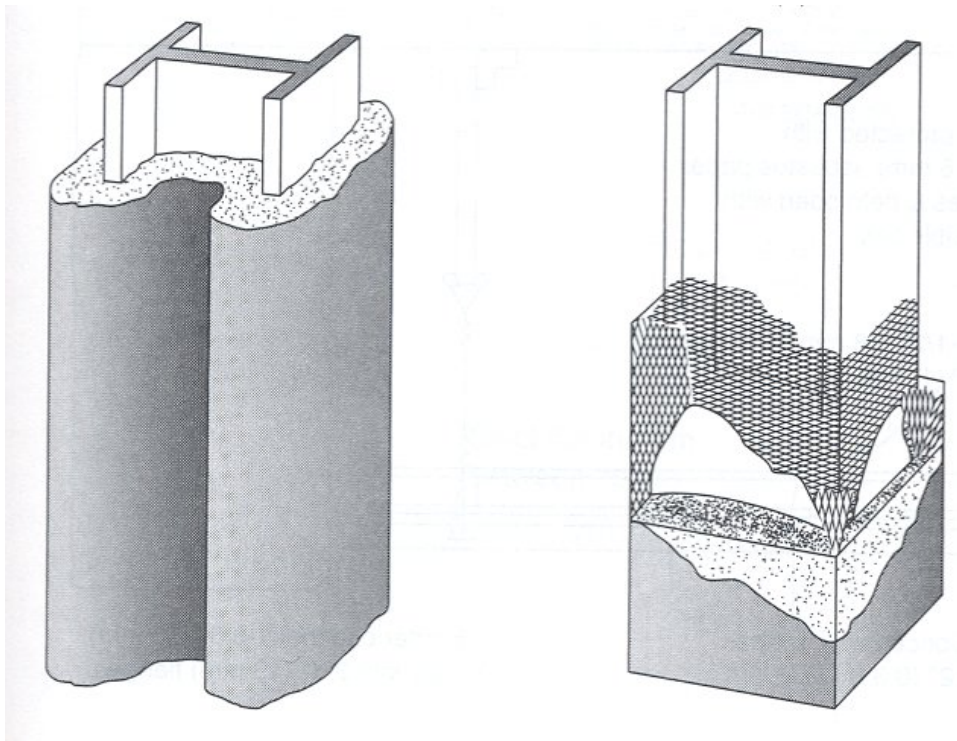
Typical E119 Test for Floor Assembly.....



ASTM E119.....

Failure criteria for steel assemblies

- For floor assemblies (steel beams and floor slabs):
 - temperature on unexposed surface reaches 140°C
 - ignition of cotton waste on unexposed surface
- Inability to sustain applied load
- Steel temperature reaches limiting value of approx. 600°C



Limitations of ASTM E119

- **Scaling**
- **Extrapolation**
- **Boundary Conditions / Interaction of structural elements**
- **Loading**
- **No connections included in test**
- **Cool-down phase of fire not represented in test**

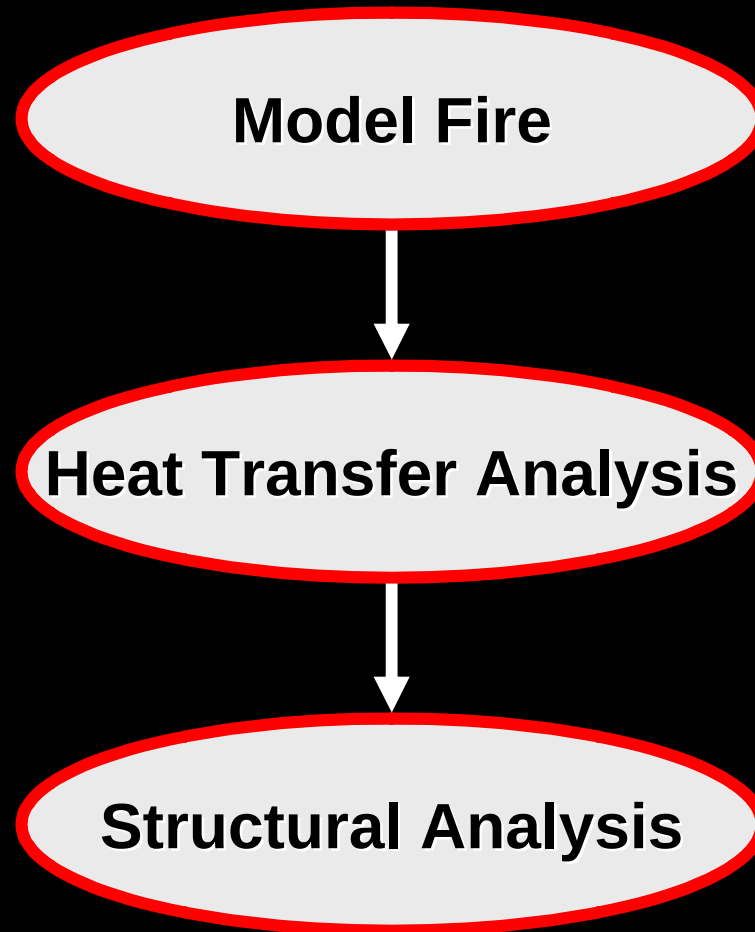
Limitations of ASTM E119

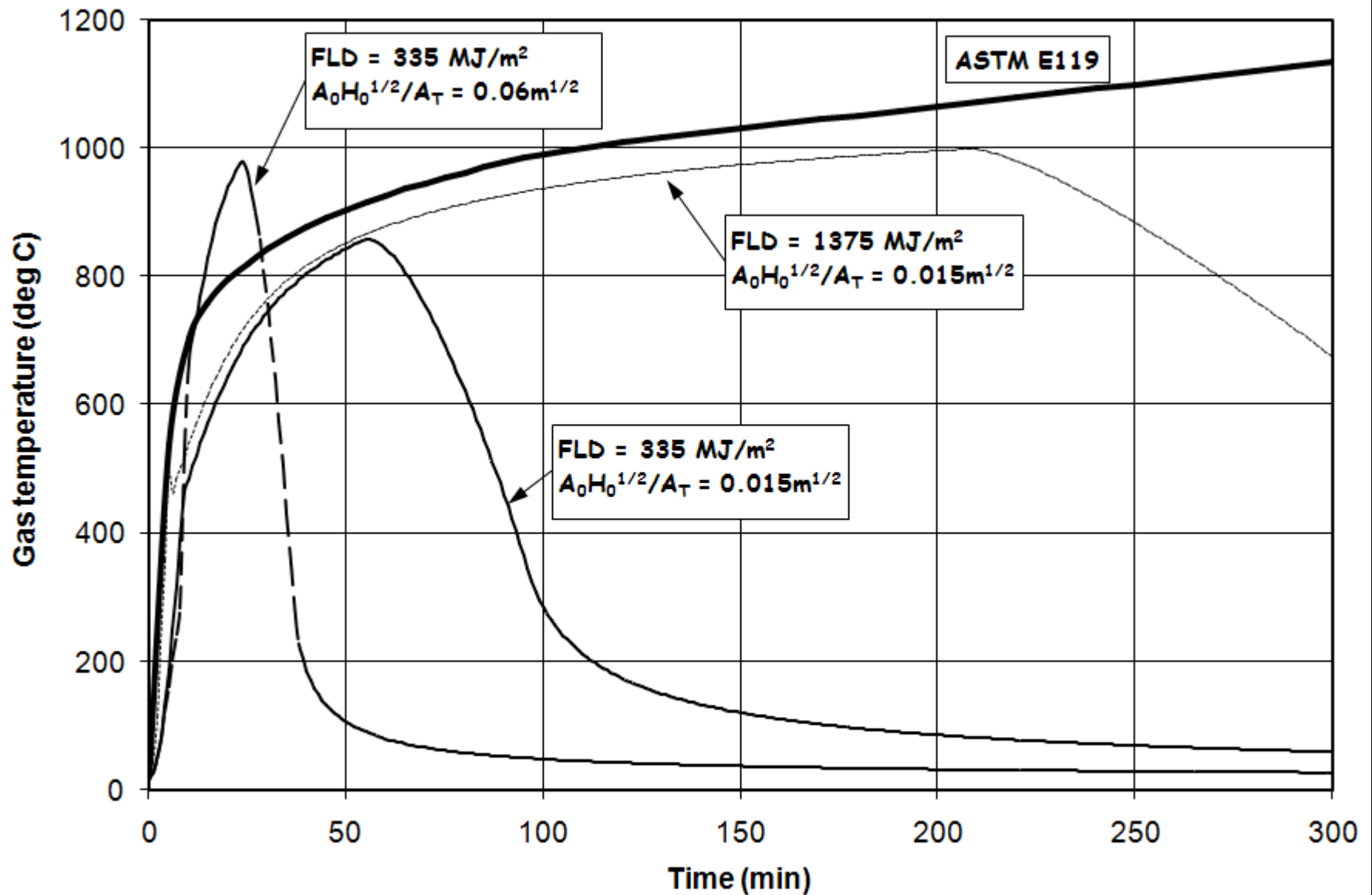
NIST recommendation based on WTC collapse study.....

"NIST recommends that the technical basis for the century-old standard for fire resistance testing of components, assemblies, and systems be improved through a national effort."

Future Direction....

Engineered Structural Fire Safety



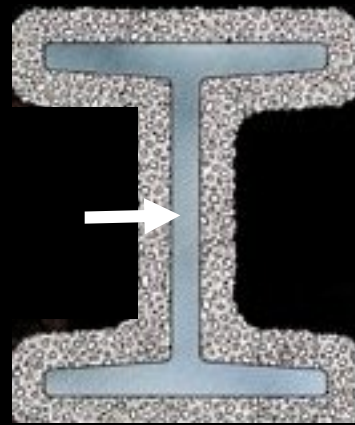


Compartment Fire Analysis

Heat Transfer Analysis



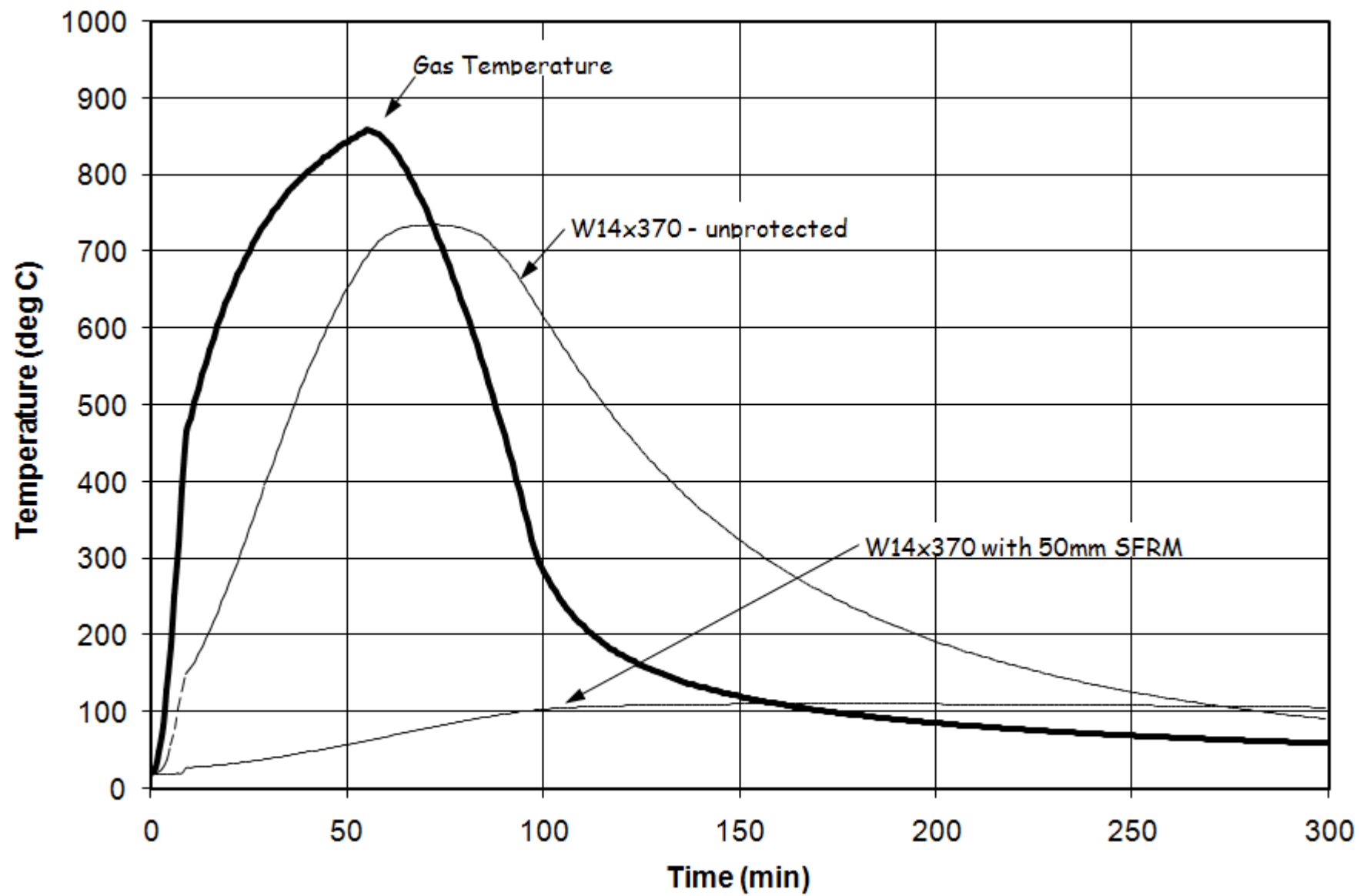
Radiative and
Convective Heat Flux
(Inferred from gas
temperatures)



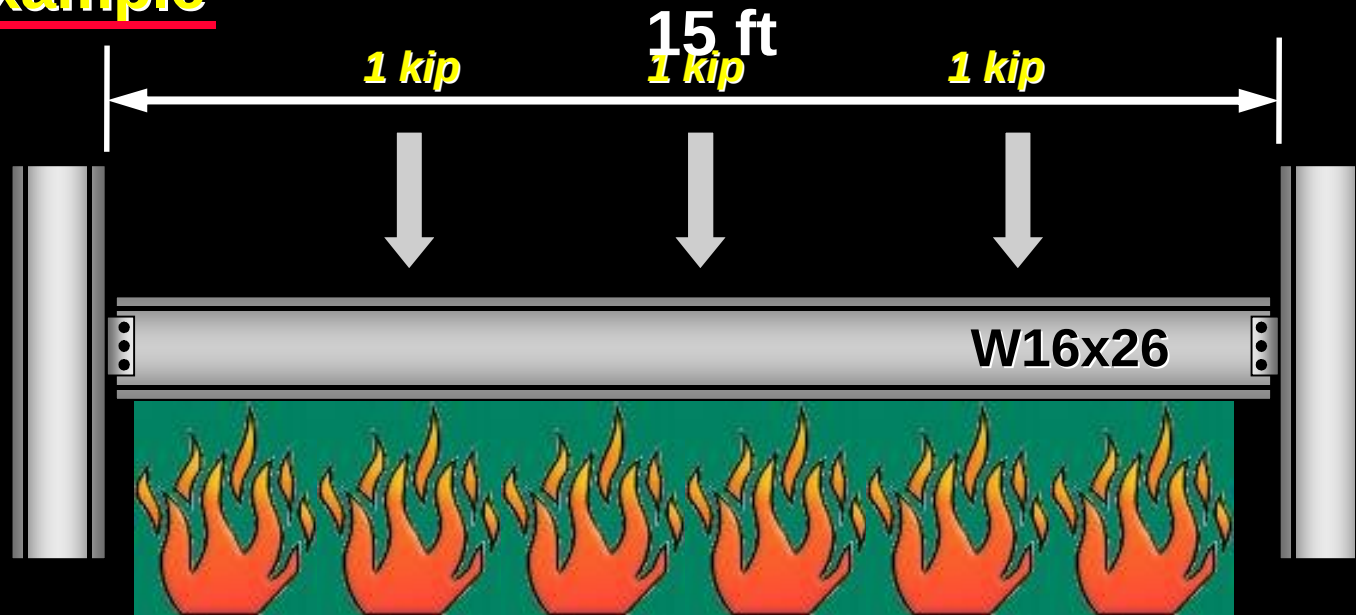
Heat Conduction within
member

**Structural
Member
Temperatures
depend on:**

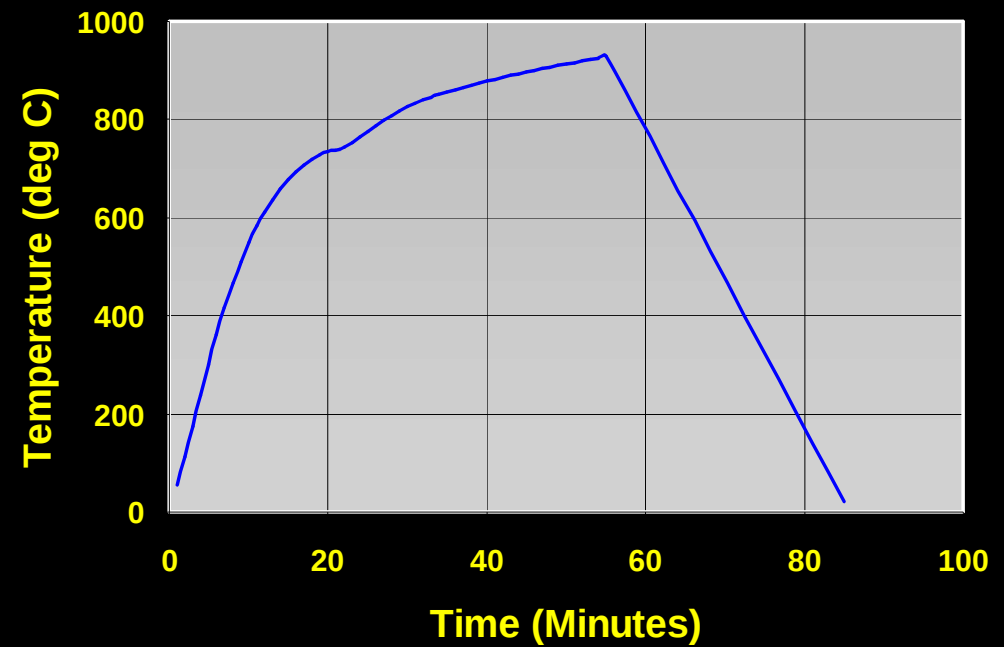
- **Temperature
of fire
environment**
- **Thermal
properties of
structural
member and
insulation**



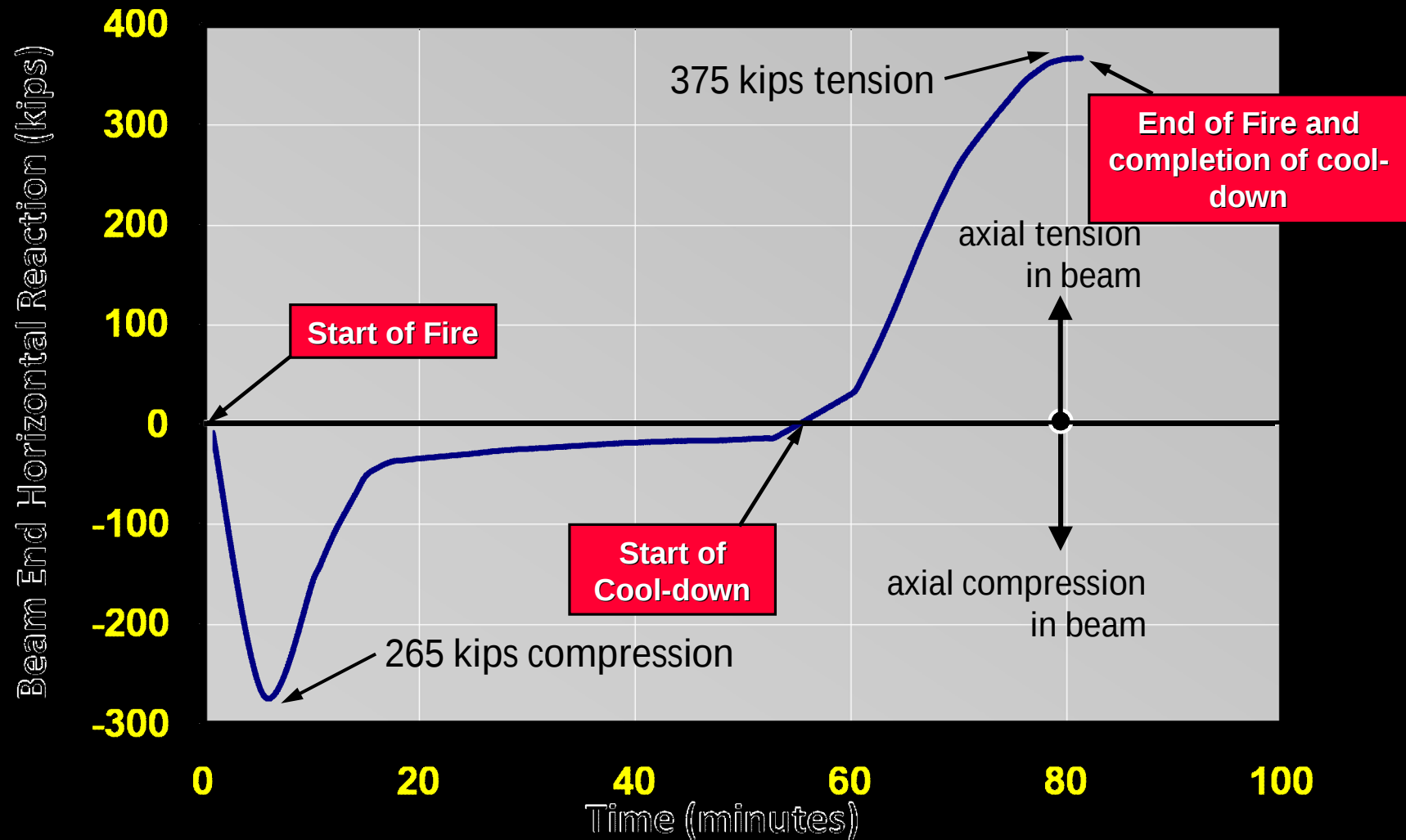
Example



Assumed Beam Heating
and Cooling Due to Fire:



Analysis Results: Beam End Horizontal Reaction



Closing Observations

- **The US sustains large annual human and economic losses due to fire.**
- **Structural fire safety is a key element of overall building fire safety.**
- **Current approach for structural fire safety is technically flawed.**

Closing Observations

- **Structural fire safety is fundamentally a structural engineering problem..... currently done with little or no involvement of structural engineers.**
- **More cost effective structural fire safety can likely be achieved by moving from current prescriptive approach to engineered structural fire protection.**

What's Needed to Move Forward?

Technical Barriers.....

- **Design and performance criteria.**
- **Improved tools for fire-thermal-structural analysis.**
- **Improved criteria to predict structural capacity at elevated temperatures.**
- **Research quality experimental data on structural response at elevated temperature.**

What's Needed to Move Forward?

Professional Barriers.....

- **Recognition that structural fire safety must be the responsibility of Structural Engineers**
- **Education of Structural Engineers in fire safety**