CLOUD CEILINGS: FIRE DYNAMICS AND CODE CONTEXT

November 7, 2016
AGENDA

- Introduction
- New York State Code - Update
- Ceiling Types
- Fire Dynamics
- Compartment Fire Growth
- Effects of Fire Location within Compartment
- Code Requirements and Cloud Ceiling (NFPA 13)
- Code Requirements and Cloud Ceiling (NFPA 72)
- Conclusions and Questions
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Education:
- B.S. Mechanical Engineering – WPI (2012)

Work Experience:
- Exponent, Inc. (2013-2016)
  - Fire Protection Engineering Failure Analysis
  - Fire Origin & Cause
  - U.S. Army Rapid Equipping Force - Deployment to Afghanistan
- Peterson Guadagnolo Consulting Engineers PC (2016-Present)
  - Fire Protection Engineering
    - Fire Suppression Systems
    - Fire Alarm and Detection Systems
  - Sustainability Engineering
    - Rainwater Collection & Reuse
NEW YORK STATE CODES
BUILDING CODE UPDATE

Important Dates:

- Adoption period: April 6, 2016
- Transition period: Both 2010 & 2016 codes allowed
- Full effective date: October 3, 2016

+ NYS Amendments
NEW YORK STATE CODE REFERENCE STANDARDS

2010 Building Code of New York State
- ICC Model Code – 2009 Series
  - NYS Amendments
- NFPA 13 – 2007
- NFPA 72 – 2007

2016 Building Code of New York State
- ICC Model Code – 2015 Series
  - NYS Amendments
- NFPA 13 – 2013
- NFPA 72 – 2013

Industry Standards
- ICC Model Code – 2015 Series
- NFPA 13 – 2016
- NFPA 72 – 2016
NFPA 13 (2016) – CEILING TYPES

- Flat Ceiling (3.3.5.2) – Continuous ceiling in a single plane
- Horizontal Ceiling (3.3.5.3) – Ceiling with a slope not exceeding 2 in 12.
- Sloped Ceiling (3.3.5.4) – Ceiling with a slope exceeding 2 in 12.
- Smooth Ceiling (3.3.5.5) – Continuous ceiling free from significant irregularities, lumps, or indentations.
**NFPA 72 (2016) – Ceiling Types**

- Ceiling (3.3.35) – Upper surface of a space, regardless of height. Areas with a suspended ceiling have two ceilings, one visible from the floor and one above the suspended ceiling.

- Level ceiling (3.3.35.1) – Ceilings that are level or have a slope of less than or equal to 1 in 8

- Sloping ceiling (3.3.35.2) – Ceilings that have a slope of more than or equal to 1 in 8
NFPA – Ceiling Types - Clouds

- NFPA 13 (2016) – NEW – Definition for cloud ceiling
  - 3.3.5.1 Cloud ceiling – *any ceiling system installed in the same plane with horizontal openings to the structure above on all sides. This does not include sloped ceilings.*

- “[C]loud ceiling is simply a suspended ceiling that covers only a portion of a room or space below”

NFPA – CEILINGS TYPES – OPEN GRID

- NFPA 13 (2016) A.3.7.2.(2) – Open-grid ceilings… refers to ceilings in which the openings are ¼" or larger in the least dimension, the thickness of the ceiling does not exceed the least dimension of the opening, and the openings constitute at least 70 percent of the ceiling area.

- NFPA 72 (2016) contains same definitions for open-grid ceilings.
FIRE DYNAMICS

Fire Triangle
HEAT RELEASE RATE

FIGURE 3.11.3 Time Scales Associated with Fire Hazard Development and Mitigation
**Fire Dynamics - Plumes**

**Figure 2.4.2** Fire in the Open. Note: A = source of fire.

**Figure 2.4.3** Fire Under Ceiling, Far from Walls. Note: A = source of fire.
COMPARTMENT FIRE GROWTH
COMPARTMENT FIRE GROWTH – INITIAL STAGES

FIGURE 2.4.4 Initial Ceiling Effect. Note: A = source of fire. B = target fuel.
COMPARTMENT FIRE GROWTH – SMOKE LAYER DEVELOPMENT

FIGURE 2.4.5 Initial Smoke Discharge from Compartment of Origin. Note: A = source of fire. B = target fuel.
COMPARTMENT FIRE GROWTH – SMOKE LAYER DEVELOPMENT

**FIGURE 2.4.6** Increasing Fire Size and Layer Depth. Note: A = source of fire. B = target fuel.
COMPARTMENT FIRE GROWTH – FLASHOVER

**FIGURE 2.4.9** Flashover—Transition to Full-Room Involvement. Note: A = source of fire. B = target fuel.
COMPARTMENT FIRE GROWTH – POST-FLASHOVER CONDITION

FIGURE 2.4.10  Full-Room Involvement (Postflashover). Note: A = source of fire, B = target fuel.
EFFECTS OF FIRE LOCATION WITHIN COMPARTMENT
**FIRE LOCATION WITHIN COMPARTMENT**

- Decrease in air entrainment
- Increase in flame height

**FIGURE 2.4.11** Effect of Fire Location on Air Entrainment

*Figure 4-13.8. Wall and corner plume diagrams.*
FIRE LOCATION WITHIN COMPARTMENT

FIGURE 2.4.11 Effect of Fire Location on Air Entrainment
FIRE LOCATION WITHIN COMPARTMENT

FIGURE 2.4.11 Effect of Fire Location on Air Entrainment

Cloud Ceiling

Direction of airflow
FIGURE 2.4.11  Effect of Fire Location on Air Entrainment
CLOUD FIRE LOCATION– FREE OPEN

Cloud Ceiling

Losses to ceiling

Air entrainment

Ceiling jet

Plume centerline

Turning region

Air entrainment

Fire Location
“Free Open”

Cloud Ceiling

Fire Under Suspended “Cloud” Ceiling
Cloud Fire Location – Wall Fire

Fire Under Suspended “Cloud” Ceiling

Cloud Ceiling

Fire Location “Wall Fire”
**CLOUD FIRE LOCATION—CORNER FIRE**

Fire Under Suspended “Cloud” Ceiling

Note: Relative size of ceiling jets depends on the fire, and room and cloud geometry.

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**Figure 4-126. Wall and corner plume diagrams.**

**Fire Location “Corner Fire”**

Cloud Ceiling

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**FIGURE 2-4.11 Effect of Fire Location on Air Entrainment**
CODE REQUIREMENTS AND CLOUD CEILINGS

- NFPA 13
- NFPA 72
NFPA 13

NFPA 13 (2016) – CLOUD CEILINGS

8.15.1.2.1.3 - Small openings sprinkler omission requirements

- *Space above cloud ceiling...having openings with combined total area of not more than 20 percent of the ceiling, construction feature or plane used to determine the boundaries of the concealed space shall be permitted.*

Cloud Ceiling

Total opening area must be less than 20% of ceiling area to omit sprinkler coverage above the cloud ceiling.
8.15.24 (A.8.15.24.1) - Cloud ceiling sprinkler omission requirements

A.8.15.24.1(1) To determine the maximum allowed gap distance for omission of sprinklers above cloud ceilings, the following formula can be used:

\[
\frac{A}{B} = X \tag{A.8.15.24.1}
\]

where:
- \( A \) = inches of gap between clouds or between a cloud and a wall
- \( B \) = ceiling height
- \( X \) = maximum inches of gap

Example:
- \( A = 9 \) in. maximum gap dimension
- \( B = 14 \) ft ceiling height
- \( X = 0.64 \) in. of gap/ft of ceiling height

Therefore, \( \leq 0.75 \) in. of gap/ft of ceiling height spacing used.

Note: maximum gap distance allowed is 1” gap per 1’ of ceiling height for omission of sprinklers above cloud.
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<table>
<thead>
<tr>
<th>Ceiling Cloud Width (ft)</th>
<th>Maximum Area (ft²) for Opening Width ≤0.5 in./ft</th>
<th>Maximum Area (ft²) for Opening Width ≤0.75 in./ft</th>
<th>Maximum Area (ft²) for Opening Width ≤1 in./ft</th>
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<tbody>
<tr>
<td>2–&lt;2.5</td>
<td>175</td>
<td>70</td>
<td>NP</td>
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<tr>
<td>2.5–4</td>
<td>225</td>
<td>120</td>
<td>70</td>
</tr>
<tr>
<td>&gt;4</td>
<td>225</td>
<td>150</td>
<td>150</td>
</tr>
</tbody>
</table>

Maximum sprinkler area of coverage below clouds

Maximum sprinkler protection area based on ceiling cloud width and opening width.
NFPA 13 (2016) – CLOUD CEILINGS

- **11.2.3.2.3.1** - Quick response design area reduction **NOT** permitted if sprinklers above cloud ceilings are omitted.
NFPA 13 (2016) – Cloud Ceilings

8.15.24.2 – Requirements if sprinklers are omitted from above a cloud ceiling:

- All sprinklers shall be quick response standard or extended coverage pendent or upright sprinklers.
- Maximum distance between extended coverage heads shall be 16’.
- Maximum cloud ceiling height is 20’.
- Maximum spacing shall not exceed requirements for light and ordinary hazard (Tables 8.6.2.2.1 (a) & (b)).
- Cloud ceilings shall be smooth ceiling constructions.
NFPA 72

NFPA 72 (2016) – Cloud Ceilings

NFPA 72 does not have any prescriptive requirements for omission of initiating devices in regards to cloud ceilings.

- A cloud is best referred to as a Suspended Ceiling. The code refers the reader to Section 17.7.3. which reads:

  “The location and spacing of smoke detectors shall be based upon anticipated smoke flows due to plume and ceiling jet produced by the anticipated fire...”
NFPA 72 (2016) – Cloud Ceilings

- Geometries and requirements:
  - According to NFPA 13 – Clouds must be smooth ceiling type obstruction for omission of sprinklers above cloud ceilings.
  - 17.7.3.2.3.1(2) – All points on a ceiling shall have a detector within a distance equal to or less than 0.7 times the nominal 30 ft spacing.
  - 30 ft spacing is based on smooth, flat accredited laboratory approval testing for spot detectors.
  - Detection distance is at most 21 ft (0.7x).
NFPA 72 (2016) – Cloud Ceilings

In regards to smoke detector placement, there are two types of cloud geometries to consider:

- (A) Clouds in rooms which do not require spot detection on surface of clouds (small or medium rooms).
  - Note: This may require multiple smoke detectors to achieve full coverage.

- (B) Clouds in rooms which do require spot detection on surface of clouds (large rooms).
  - Note: This requires multiple smoke detectors to achieve full coverage.
Smoke layer will bank and fill area above cloud prior to device detection.
Cloud Ceilings – Smoke Detector Placement – Small Room

Optimal smoke detector location in terms of economics and maintainability.
CLOUD CEILINGS – SMOKE DETECTOR PLACEMENT – LARGE ROOM

Area not covered by smoke detector

45' x 45' room
42' x 42' cloud

Area not covered by smoke detector (worst case)
CLOUD CEILINGS – SMOKE DETECTOR PLACEMENT – LARGE ROOM

- Smoke Detector Spacing
- 45' x 45' room
- 42' x 42' cloud
- Area not covered by smoke detectors
- 45' x 45' room
- 42' x 42' cloud
- Area not covered by smoke detectors (worst case)
CLOUD CEILINGS – SMOKE DETECTOR PLACEMENT – LARGE ROOM

45' x 45' room
42' x 42' cloud

Total Room Coverage with Five Smoke Detectors
REALISTIC VIEW OF LARGE ROOM WITH MULTIPLE CLOUD CEILINGS
QUESTIONS

1. If a fire were located in the corner of a room, would the flame height in the corner be taller or shorter when compared to a similar fire located in the center of a room?

2. True or False: NFPA 13 does not and NFPA 72 does contain prescriptive requirements on cloud ceilings.

3. Can sprinklers be eliminated from above cloud ceilings?

4. In which location is a smoke detector most effective in a small room (14 feet square) with a cloud ceiling?

SOURCES

- Building Code of New York State (2010 and 2016 Editions)