Spatial Separation

Building Officials Association of BC

February 2026

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FIRE SCIENCE & ENGINEERING

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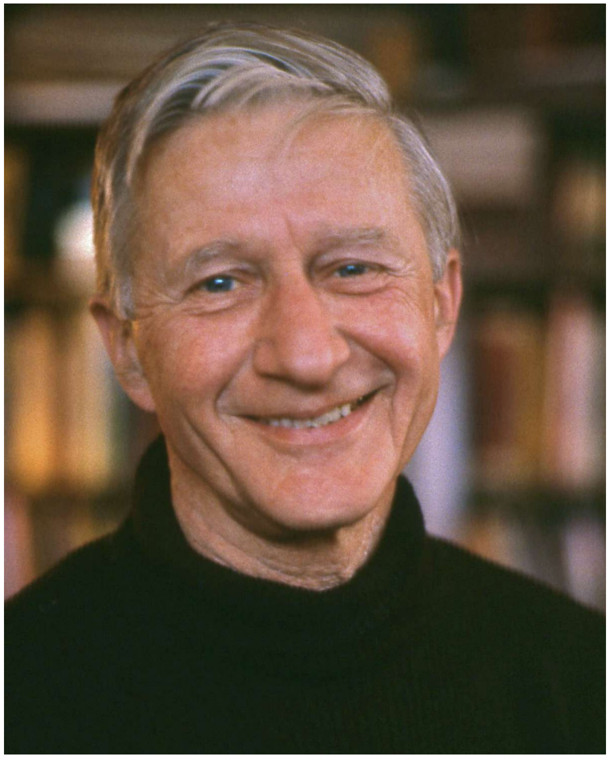
In the broadest sense, building regulations develop from contingency to contingency. Each one represents an emergency measure taken with very little or no study. As the emergency recedes, the regulation tends to form part of traditional practice. It is added to the pile, which grows and grows.

Progress towards better regulations in this country will be speeded when we have an understanding of the history of the regulations which are now enforced.

R.S. Ferguson, Architect, NRC, 1952 to 1976



Overview

- Learn the history of how and why we have spatial separation requirements in our construction codes.
- Explain the principles of how radiated heat may lead to the spread of fire from one building to another or between fire compartments.
- How the Tables were developed
- Discuss the impacts of concentrated openings

A Short History

Conflagration

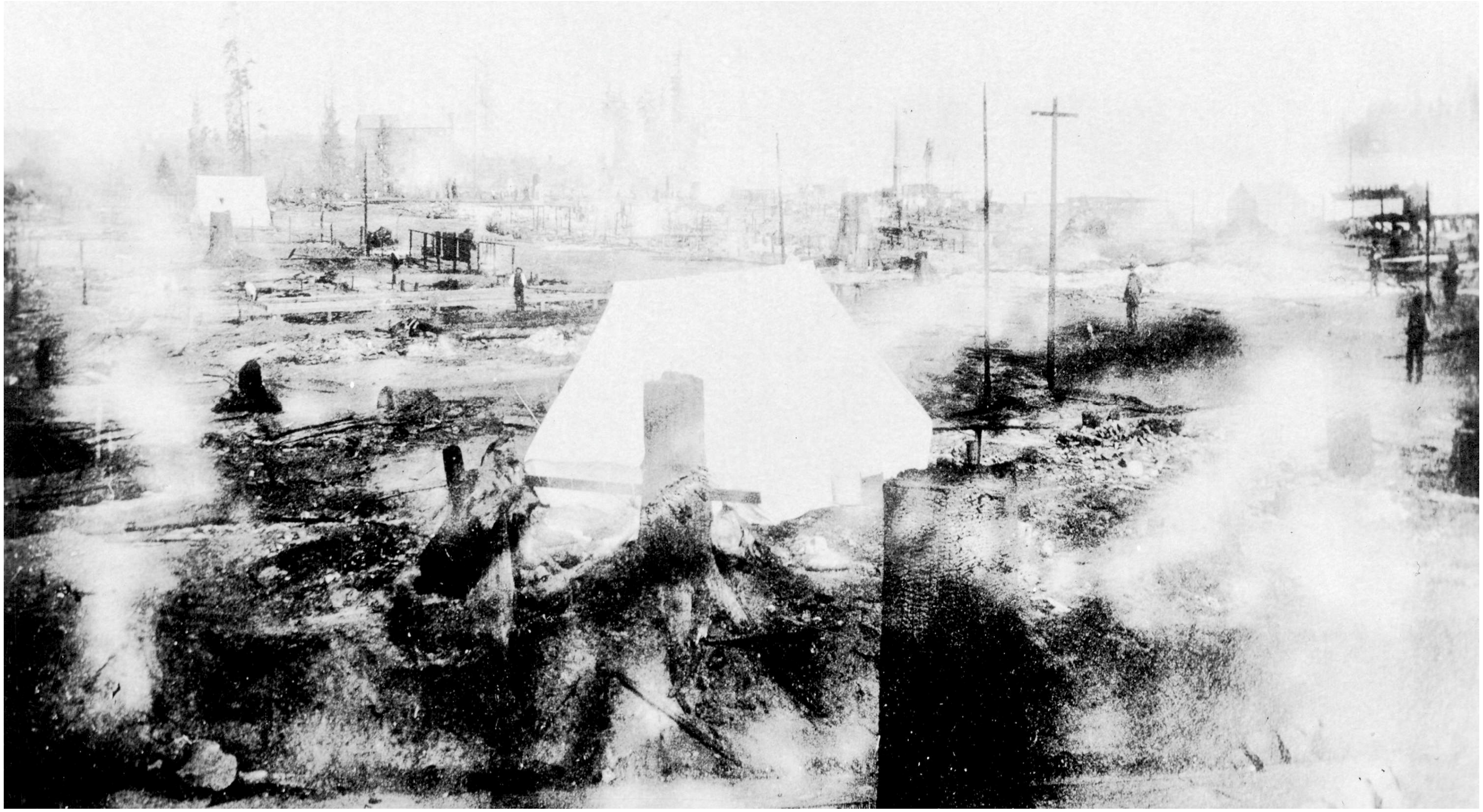
- A great and destructive fire; the burning or blazing of a large extent or mass of combustible matter, e.g. of a town, a forest, etc.

Great Fire of London 1666

Great Fires of Chicago and Boston: 1871 and 1872

Great Fire of Toronto: 1904

Great Fire of Vancouver: 1886



Canadian Conflagrations to 1918

- Halifax – 1750
- Quebec – 1759
- Montreal – 1765
- Montreal – 1768
- Montreal 1803
- Quebec – 1815
- Fredericton – 1825
- Quebec – 1834
- St. John – 1837
- Quebec – 1845
- St. John – 1845

- Quebec – 1846
- Toronto – 1849
- Montreal – 1849
- Montreal – 1850
- Halifax – 1850
- Montreal – 1852
- Quebec – 1854
- Montreal 1857
- Halifax – 1861
- Quebec – 1862
- Quebec – 1865

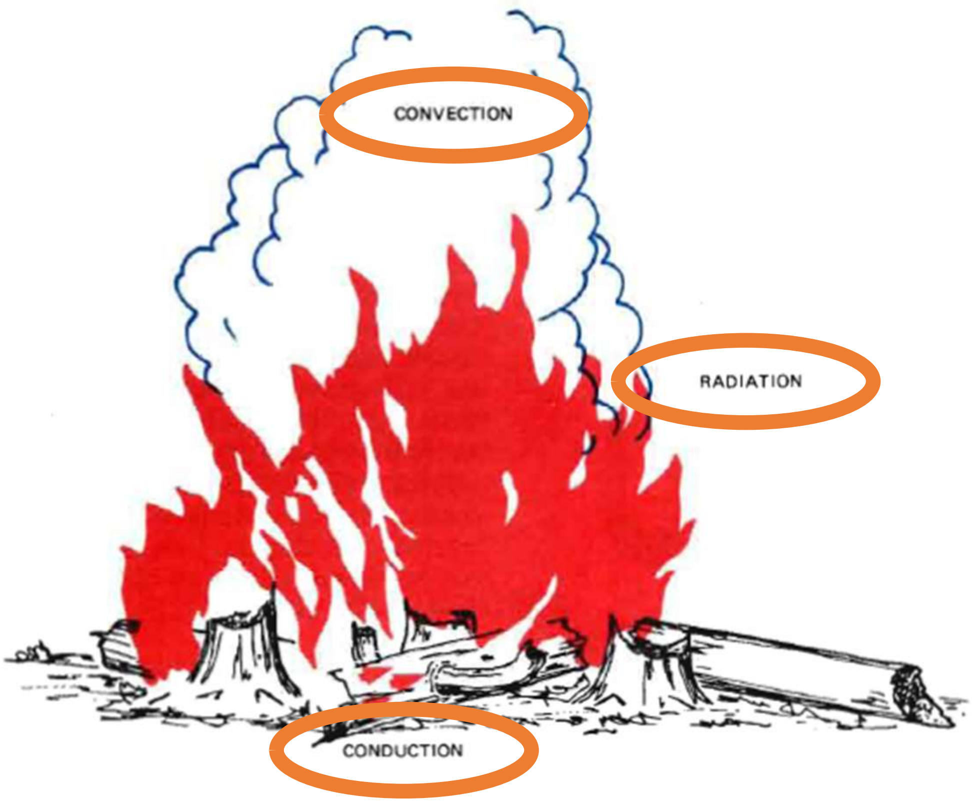
- Quebec – 1866
- Petrolia, ON – 1867
- Hull, PQ – 1870
- Quebec – 1870
- Saguenay, PQ – 1870
- Ottawa – 1874
- Quebec – 1876
- St. Johns, PQ – 1876
- Montreal – 1856
- St. Hyacinthe, PQ – 1876
- St. John – 1877

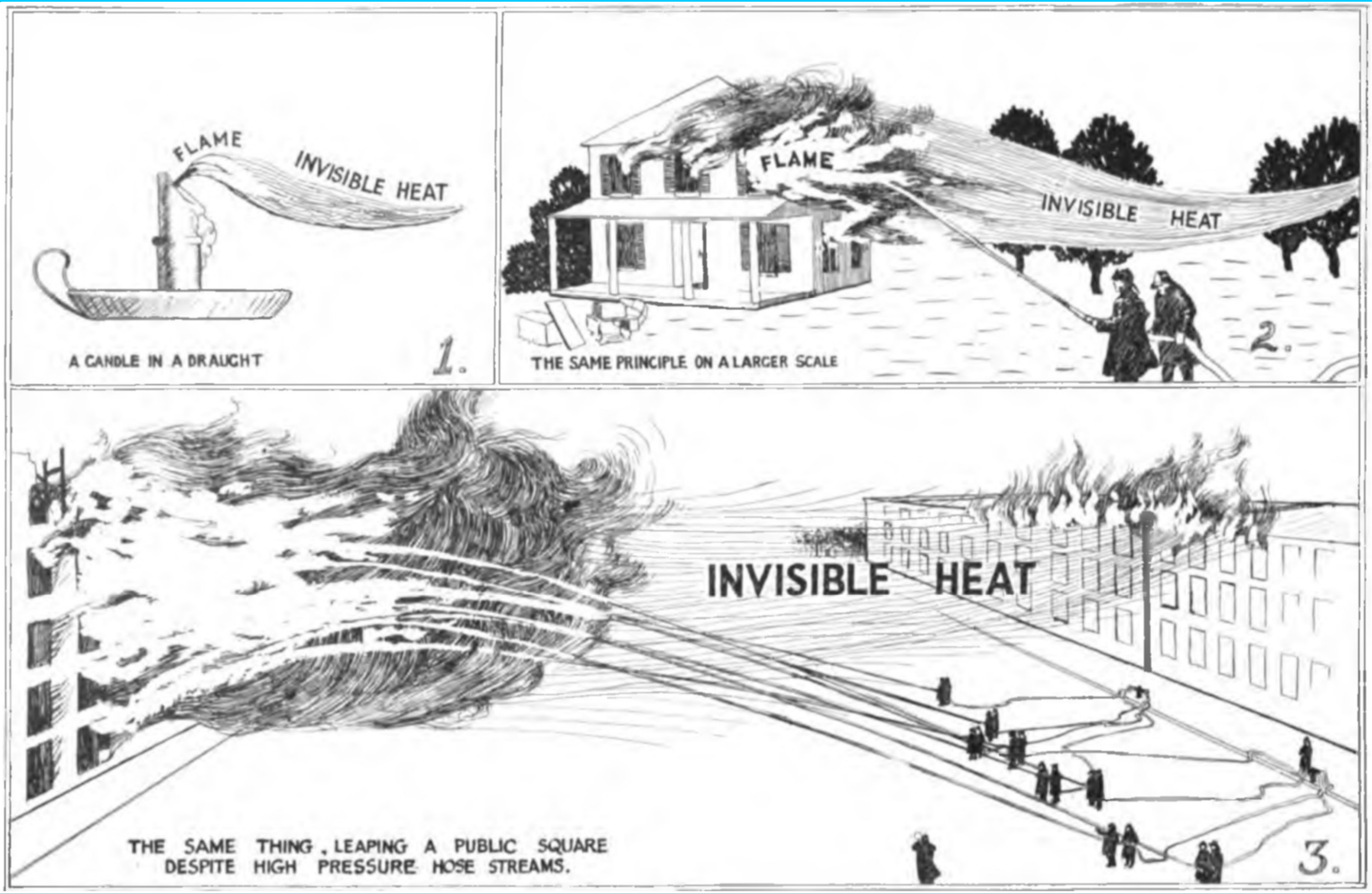
- Quebec – 1881
- Vancouver, BC – 1886
- Toronto – 1890
- Toronto – 1895
- Windsor, NS – 1897
- New Westminster, BC – 1898
- Ottawa-Hull – 1900
- Montreal – 1901
- Sydney, NS – 1901
- Ottawa – 1903
- St. Hyacinthe, PQ – 1903

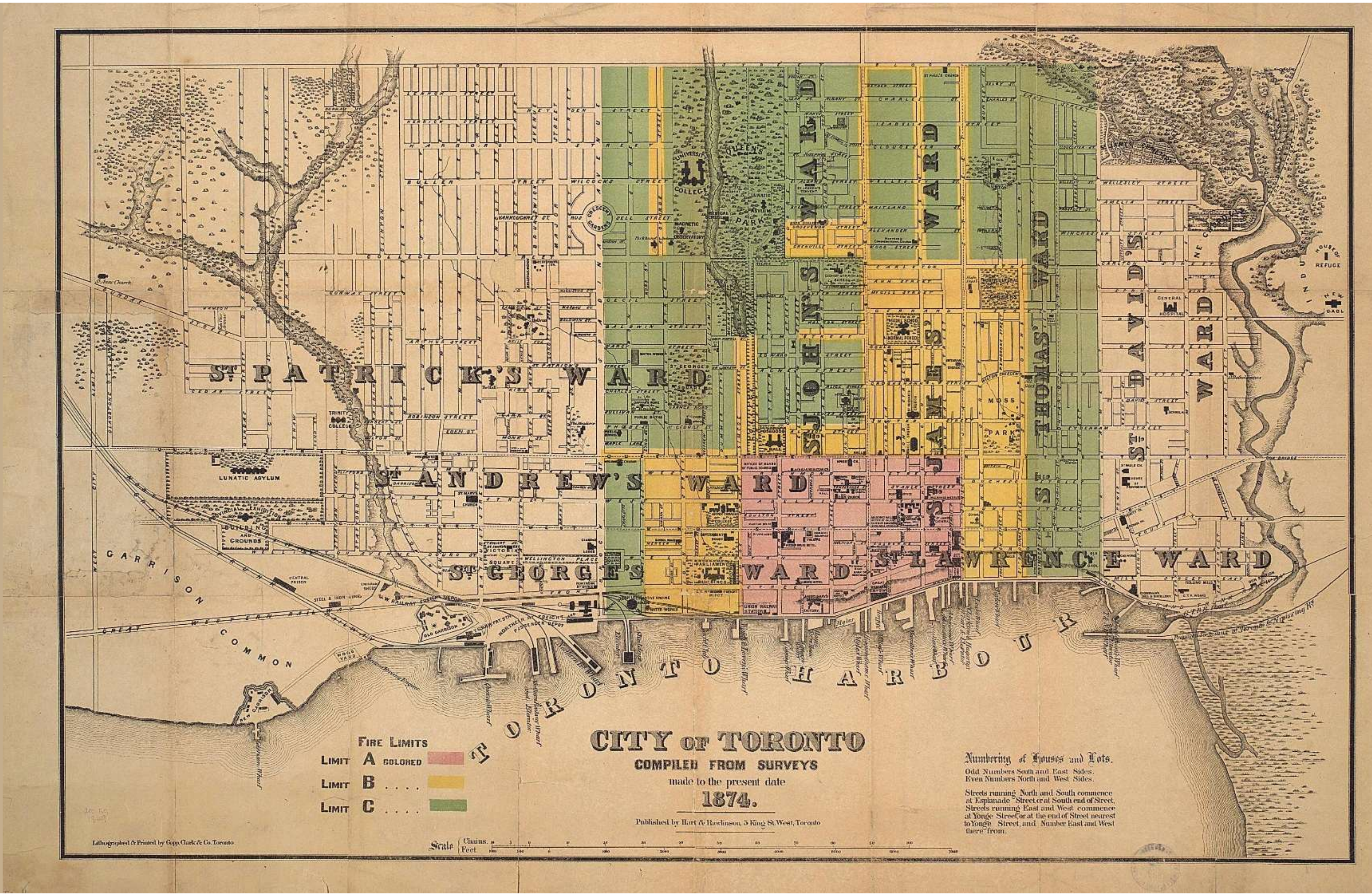
- Toronto – 1904
- Victoria – 1904
- Three Rivers, PQ – 1908
- Fernie, BC – 1908
- Campbellton, NB – 1910
- Northern Ontario – 1911
- Ottawa - 1916
- Northern Ontario – 1916
- Halifax - 1917

Science and Code Development in Canada

Mechanisms of Heat Transfer – Review




FLAME
INVISIBLE HEAT
A CANDLE IN A DRAUGHT
1.
FLAME
INVISIBLE HEAT
THE SAME PRINCIPLE ON A LARGER SCALE
2.
INVISIBLE HEAT
THE SAME THING, LEAPING A PUBLIC SQUARE DESPITE HIGH PRESSURE HOSE STREAMS.
3.


CITY OF TORONTO
COMPILED FROM SURVEYS
made to the present date
1874.
Published by Hart & Rawlinson, 5 King St. West, Toronto
FIRE LIMITS
LIMIT A COLORED
LIMIT B . . . .
LIMIT C . . . .
Numbering of Houses and Lots.
Odd Numbers South and East Sides.
Even Numbers North and West Sides.
Streets running North and South commence at Esplanade Street or at South end of Street. Streets running East and West commence at Yonge Street or at the end of Street nearest to Yonge Street, and Number East and West there from.
Lithographed & Printed by Copp, Clark & Co. Toronto
Scale Chains. Feet
ST PATRICK'S WARD
ST ANDREW'S WARD
ST GEORGE'S WARD
ST JOHN'S WARD
ST JAMES' WARD
ST THOMAS' WARD
ST DAVID'S WARD
ST LAWRENCE WARD
TORONTO HARBOUR
GARRISON COMMON
LUNATIC ASYLUM
QUEEN'S PARK
MOSS PARK

Challenges with Early Fire Limits

- Early History of Development of Requirements
  - Limits Calgary 1913:

"(a) The First Class Fire Limits will be pronerty within the following limits -

"The following defined area of the City of Calgary shall be known as the First Class Fire limits, that is to say, all the area lying within the following boundaries, namely:-

Commencing at the intersection of 6th Ave. and a point 125 feet West of 4th St. W., running easterly along 6th Ave., to the intersection of 2nd St. E. and 6th Ave., thence southerly along 2nd St. E. to the intersection of 7th Ave. thence easterly along 7th Ave. to the intersection of 4th St. E. thence southerly on 4th St. E. across the C.P.R. Right-of-way to the intersection of 11th Ave. and 4th St. E. thence westerly on 11th Ave. to the intersection of 4th St. W. thence northerly across the C.P.R. Right-of-way to the intersection of 9th Ave. thence westerly on 9th Ave to the intersection of 7th St. and 9th Ave. thence northerly on 7th St. W. to the intersection of 8th Ave. thence easterly to a point 125 feet west of 4th St. W. and 8th Ave. thence northerly to point of commencement."

  - These requirements were challenging to enforce, maintain, restrictive and city-specific
  - Needed a better "building independent" system

Canada– 1941 NBC Spatial Separation Table

TABLE 1 (SECTION 4.12)

MAXIMUM AGGREGATE AREAS OF OPENINGS IN EXTERIOR WALLS

Location of Walls or parts thereof in terms of distance from any *lot line*, or from the opposite side of a *street*, or from the centre line of a *lane*[1]	Maximum Area of Openings permitted per *storey*, in percentages of gross superficial area of wall in the *storey* — If the Exterior Wall [3] is the: Front of Building or Wall of *Outer Court*, or Recess Therefrom	Rear of Building or Wall of *Outer Court*, or Recess Therefrom	Side of Building or Wall of *Outer Court*, or Recess Therefrom	Wall of Air-well, *Inner Court*, or Recess Therefrom
Less than 4 feet	Ground Floor *Exit* Doorways Only			
Not less than 4 feet but less than 10 feet	30%	20%	15%	20%
Not less than 10 feet but less than 20 feet	40%	25%	20%	25%
Not less than 20 feet but less than 30 feet	50%	35%	25%	35%
Not less than 30 feet but less than 40 feet	60%[2]	45%	40%	45%
Not less than 40 feet but less than 60 feet	75%[2]	60%	50%	55%
Not less than 60 feet but less than 80 feet	90%	80%	70%	75%
Over 80 feet	90%	90%	90%	90%

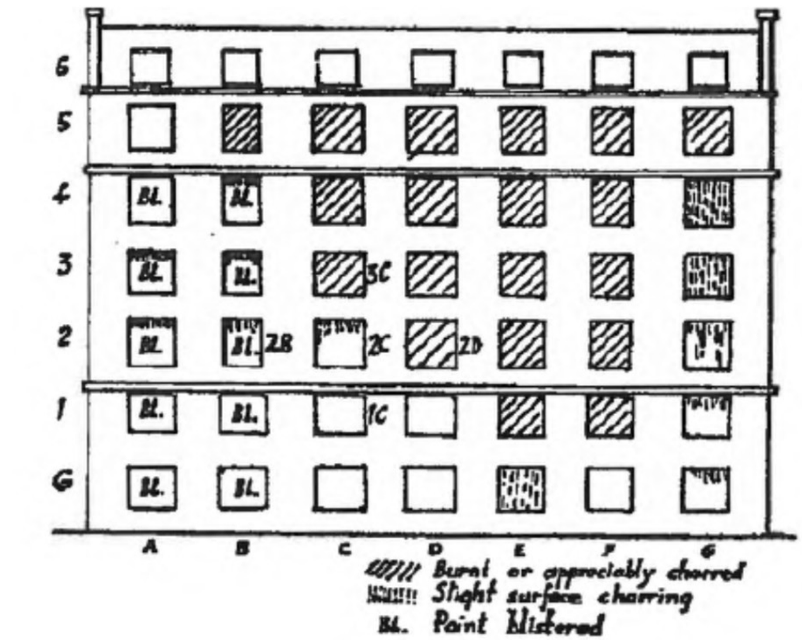


FIG. 2. ELEVATION OF EXPOSED FLATS SHOWING CONDITION OF WINDOW FRAMES AFTER FIRE

Post-War UK "Physics-Based" Approach (1950s)

- National Building Studies, London, 1950
- Spread of fire from one building to another can occur through one or a combination of the following factors:
  - Flying brands
  - Convection
  - Radiation
- Flying brands and convection addressed through protective construction
- Radiation is significant for larger fires (i.e., full building involvement)
- Ignition considerations

Shift Toward Physics-Based Spatial Separation 1953 NBC

Fire Load	*Grade of Separation*
10 lb.	grade 1
20 lb.	grade 2
30 lb.	grade 3

TABLE 3.7
Requirements for Grades of Construction and Space Separation

Column 1	Column 2	Column 3	Column 4	Column 5
Grade of Separation	Minimum Fire Resistance of Construction	Minimum Fire Resistance of Closures	Minimum Fire Resistance of Shafts(1)	Minimum Space Separation
Grade 1 Construction Separation	1 hour	¾ hour(3)	¾ hour(2)	—
Grade 2 Construction Separation	2 hours	1½ hours	1 hour	—
Grade 3 Construction Separation	3 hours	2 hours	2 hours(2)	—
Grade 4 Construction Separation	4 hours	3 hours	2 hours(2)	—
Grade 1 Space Separation	—	—	—	15 feet
Grade 2 Space Separation	—	—	—	20 feet
Grade 3 Space Separation	—	—	—	25 feet

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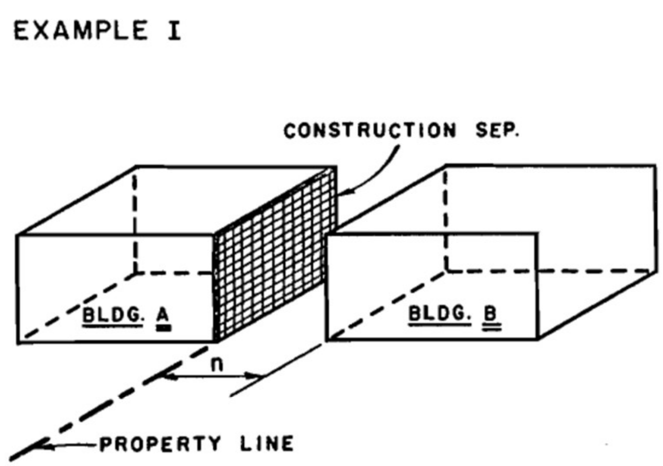
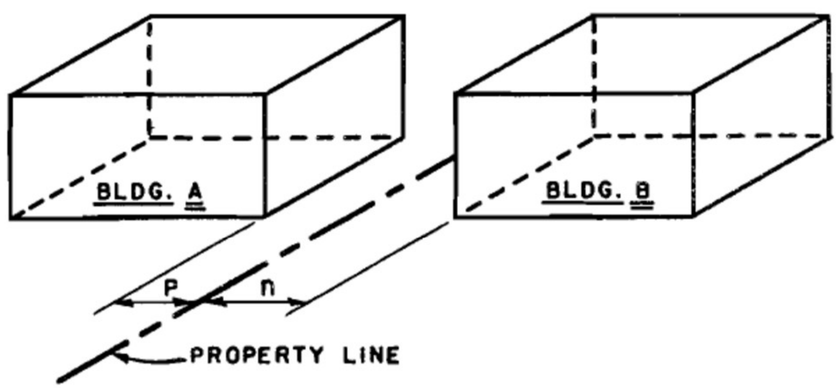
Distance vs. Protection – 1953 NBC



1. Buildings A and B are two adjacent buildings.
2. Building A is built to the property line; therefore a construction separation with no openings must be used.
3. The grade of the construction separation is determined by the fire load of building A.
4. Since a space separation (n) is being used for building B the wall facing the property line may have unlimited unprotected openings, and the wall finish need not be fire resistive, provided, however, that a non-combustible finish is used in a non-combustible building.
5. The space separation (n) is determined by the grade of separation required by the fire load of building B.

Building-Independent Approach – 1953 NBCC

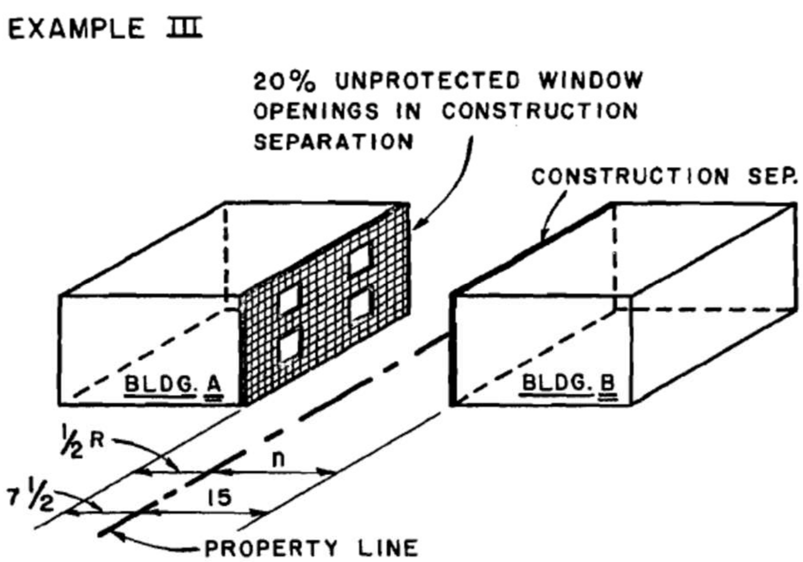
EXAMPLE II



1. Both buildings A and B use space separations.
2. (n) and (p) are determined by the grade of separation required by the fire loads of the respective buildings.
3. The same regulations apply to buildings A and B as to building B in Example I.
4. The minimum distance which (n + p) could equal is 30 feet - if both A and B have 10-lb fire loads then each is required to have an off-set of 15 feet.

Suppose building A is an office with a 10-pound fire load and building B is a store with a 20-pound fire load. In Example I building A would need a 1-hr fire wall and (n) for building B would be 20 feet. In Example II (p) and (n) would be 15 and 20 feet respectively.

Incorporating Openings – 1953 NBCC



1. Building A requires openings in the wall which do not exceed 20% of the wall area. Assuming fire loads as before, the separation requirements are as follows:

Building A

Exterior walls of 2 hours fire resistance and a side yard (p) of 7' 6" (1/2 of a Grade 1 space separation)

Building B

The owner of building B elects to use a Grade 1 construction separation plus a Grade 1 space separation thus achieving the required total Grade 2 separation.

Table Development

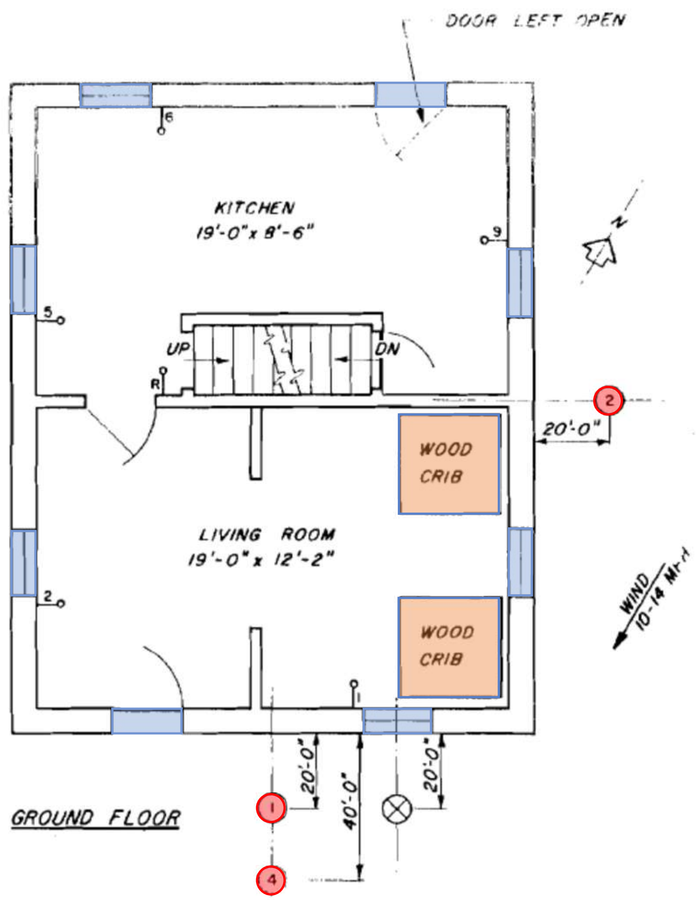
St. Lawrence Burns – Jan/Feb 1958

- St. Lawrence Burn Tests (Aultsville Ontario):
  - Six 2-storey dwellings of similar size and layout and two larger structures (school and community hall)
  - One dwelling test was eliminated due to problems
  - Current table values are primarily based on results from Test No. 4 and 5
  - Fire Service response based on Test No. 5

Do Fires Burn Hotter and Faster Today?

- Modern homes: **more energy-dense contents** (plastics, synthetics)
- Past homes:
  - **Lower energy density contents**
  - But **combustible room linings** → faster compartment fire spread
- Fire dynamics have **shifted**:
  - Today → more **content-driven fires**
  - Past → more **lining-driven fires**
- **Flashover times remain similar** to studies from the 1940s–50s

Burn House – Test Setup



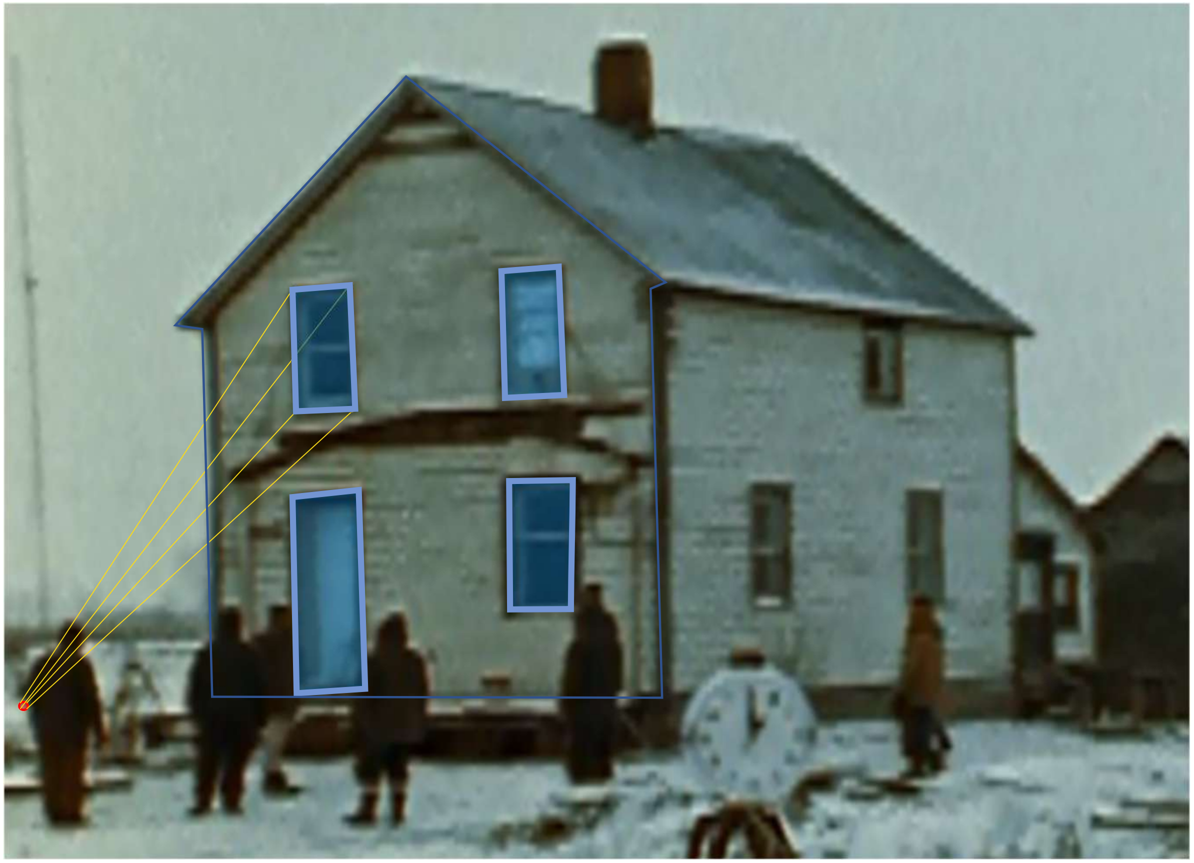
Burn House – Ignition

Burn House – Start the Clock

St. Lawrence Burns: Results

Building and Burn No.	Exterior Cladding	Interior Lining	Radiometer Location	Wind Speed	Intensity (I) cal/cm²/sec	F Configu-ration Factor of Openings	I/F cal/cm²/sec
2	Brick	Downstairs: fibreboard (walls & ceilings) except for plywood wainscot in kitchen Upstairs: plaster	15' leeward 30' leeward 15' windward	4-5 mph	0.47 0.18 0.08	0.05 0.016 0.04	9 11 2
3	Brick	Fibreboard	15' leeward 30' leeward 15' windward	13-14 mph	1.25 >0.18 0.46	0.034 0.013 0.034	37 >14 14
4	Clapboard (brick infilling to timber frame)	Plaster	20' leeward 40' leeward 20' windward	11-12 mph	0.56 0.17 0.46	0.032 0.011 0.028	18 15 16
5	Clapboard (on cedar shingles)	Pressed paper	20' leeward 40' leeward 20' side	10-14 mph	1.05 0.32 0.35	0.027 0.008 0.012	37 40 29
6 Fraternity Hall	Brick	Plaster, wooden ceiling and wainscot	20' leeward 40' leeward 20' windward	7-8 mph	0.9 >0.41 0.42	0.075 0.031 0.075	12 >13 6
7	Brick	Plaster	15' leeward 30' leeward 15' windward	13 mph	0.9 0.38 0.08	0.058 0.018 0.044	16 21 2
8 School	Brick	Plaster, wooden ceiling	20' east 40' east 20' west	very low	0.83 0.17 >0.5	0.049 0.019 0.088	17 9 > 6

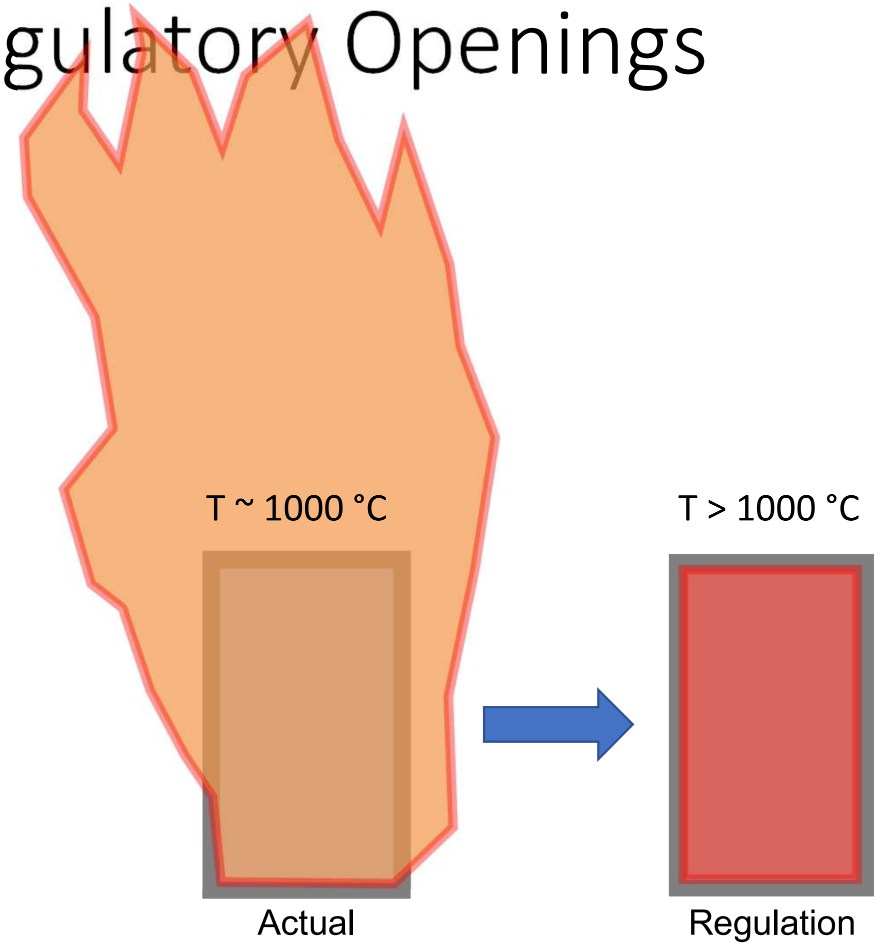
Configuration Factor as the Starting Point



From Test Data to Code – Early Challenges

From Test Flames to Regulatory Openings

- Radiation Source (Windows)
  - Actual: Significant flame extension out windows
  - Regulation: Window area theorized as the only source of radiant heat for purposes of simplification
  - High Hazard: ~2.4 x Opening Area
  - Low Hazard: ~1.2 x Opening Area



Converting Test Results into Practical Regulations

- Actual:
  - Burn No. 5 peak of 29 to 40 $cal/cm^2 \cdot s$ (1214 to 1675 kW/m^2)
  - Burn No. 4 peak ½ Burn No. 5 values
  - 1000 °C black body radiator
- Regulation:
  - Building separations associated with peak heat not practical.
  - Assume fire department intervention when peak heat reaches approx. ¼ highest values measured.
  - Heat at 10 to 11 minutes for Burn No. 5
  - Approx. 356 kW/m^2

Establishing the Benchmark Exposure Value

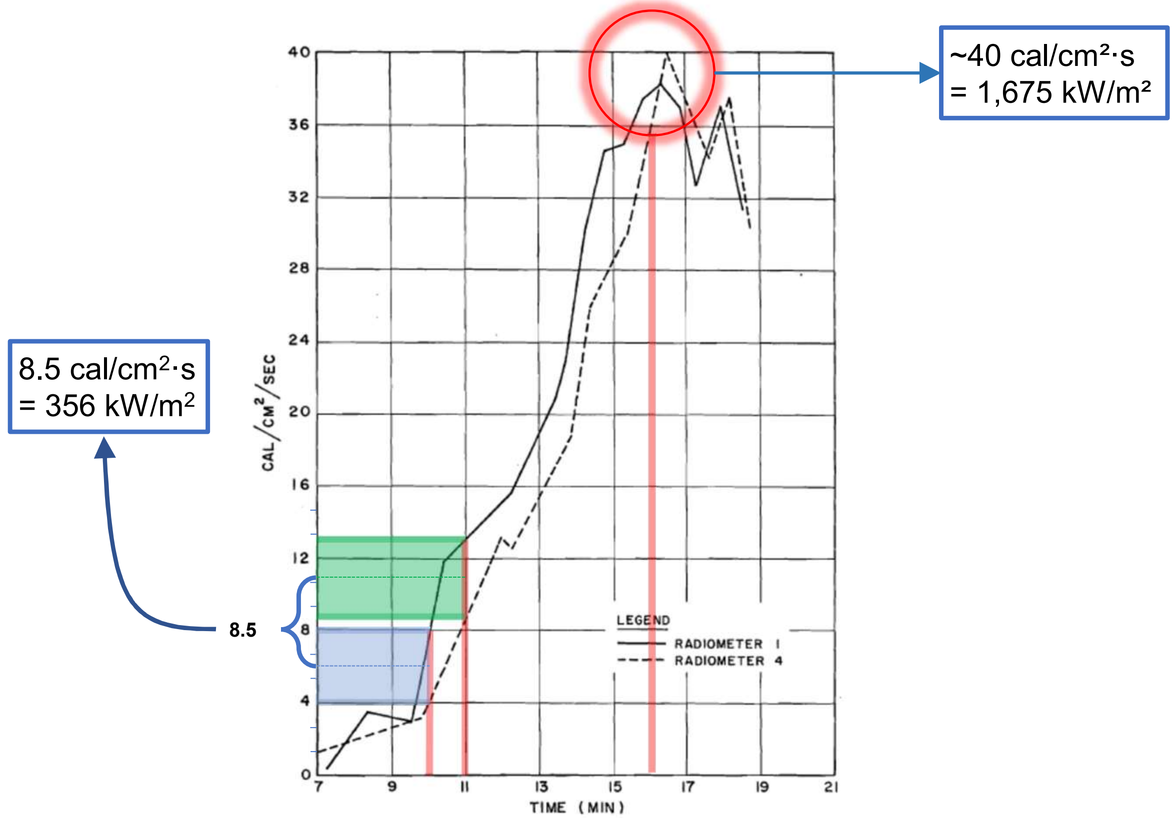


FIGURE 22 HYPOTHETICAL INTENSITIES AT WINDOW OPENINGS BURN No. 5

Defining Target Criteria for Fire Spread

- Acceptable heat flux at a target (Target Criteria):
  - Ignition of wood with piloted (🔥) source: 12.5 kW/m²
  - Autoignition of wood ~ 30 kW/m²
- Target criteria expressed as a ratio of target heat flux and peak heat:
  - High hazard (combustible lining) - Table 3.2.3.1.C $q" = \phi E = \phi e \sigma T^4$

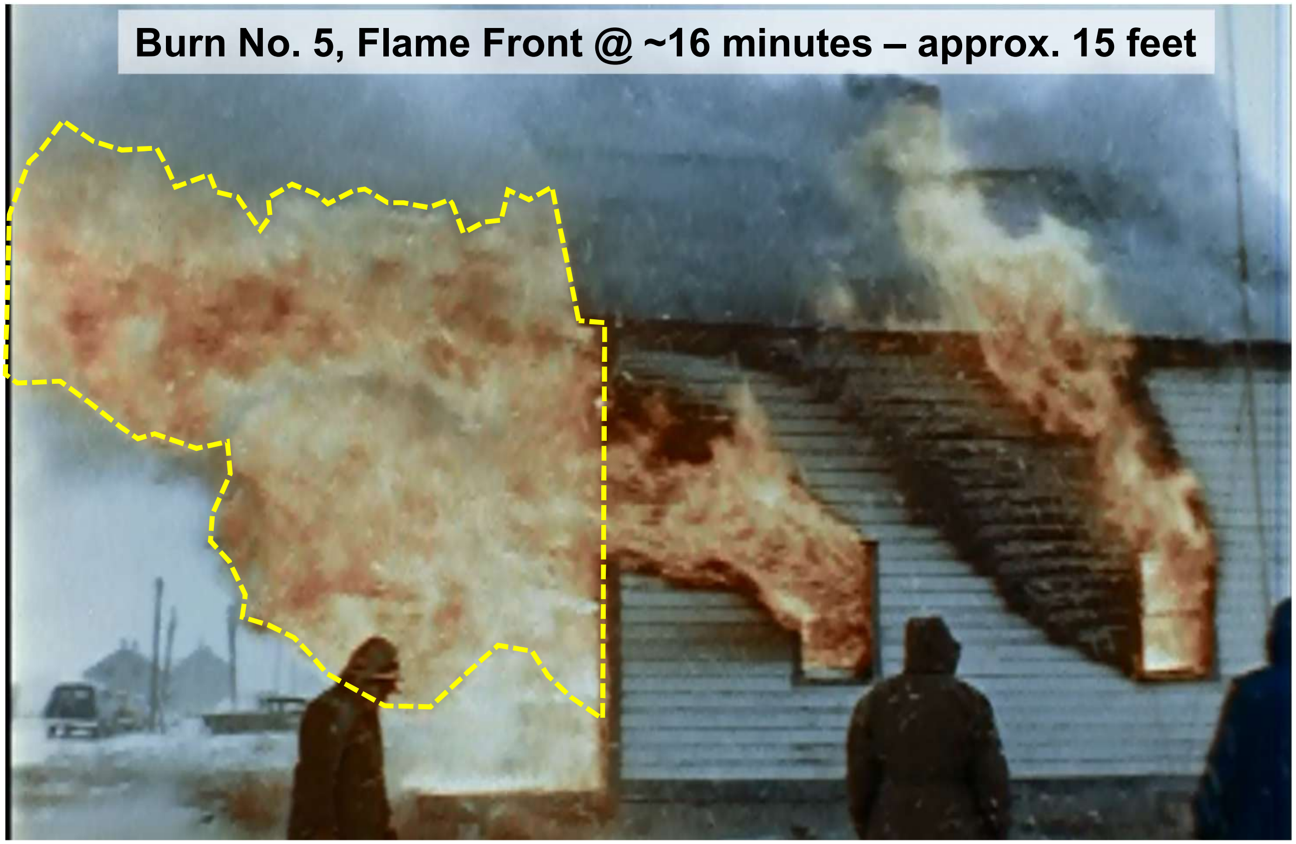
$$\phi_C = \frac{\dot{q}"}{E} = \frac{12.5\ kW/m^2}{356\,kW/m^2} = 0.035$$

  - Low hazard (noncombustible lining) - Table 3.2.3.1.B

$$\phi_C = \frac{\dot{q}"}{E} = \frac{12.5\ kW/m^2}{\frac{1}{2}356\,kW/m^2} = 0.07$$

Accounting for Flame Extension in Regulations

- Flame Front
  - Actual: Varied 2 to 7 ft within first 10 minutes
  - Initial simplification:
    - High hazard – 7 ft
    - Low hazard – 5 ft
  - Regulation: For simplification – 6 ft (~1.8 m)



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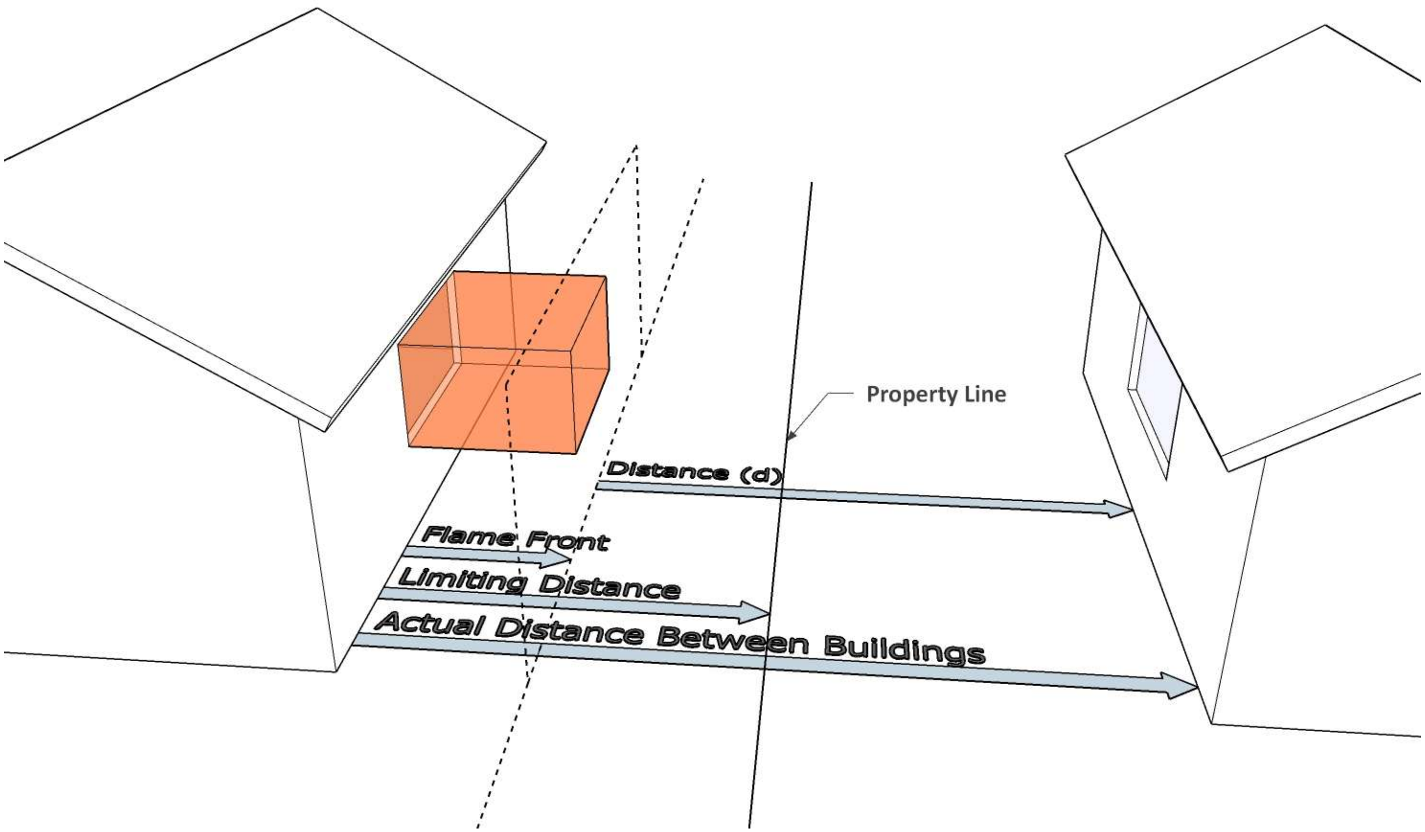
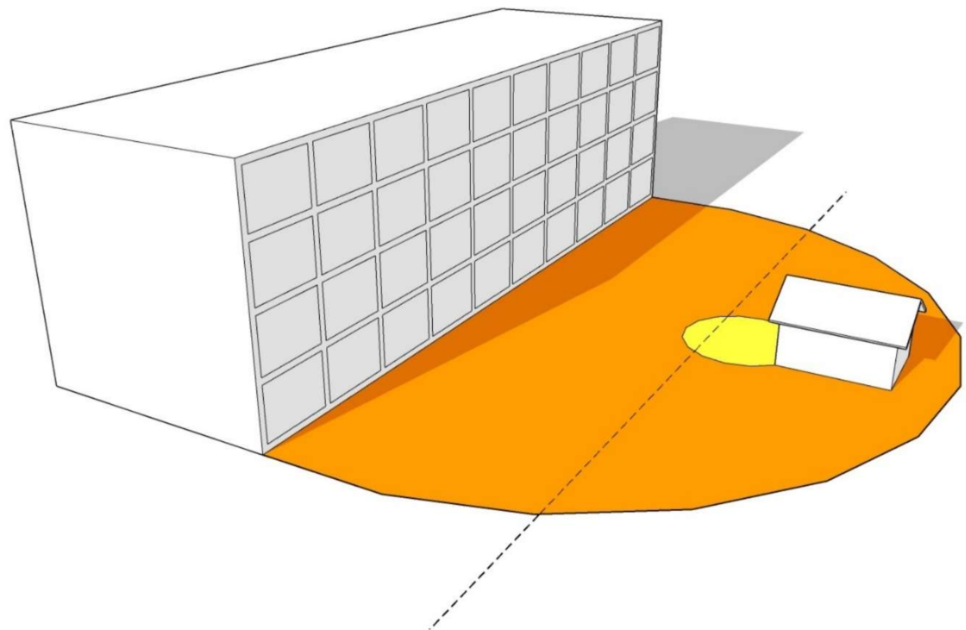
Conceptual Model for Flame Front



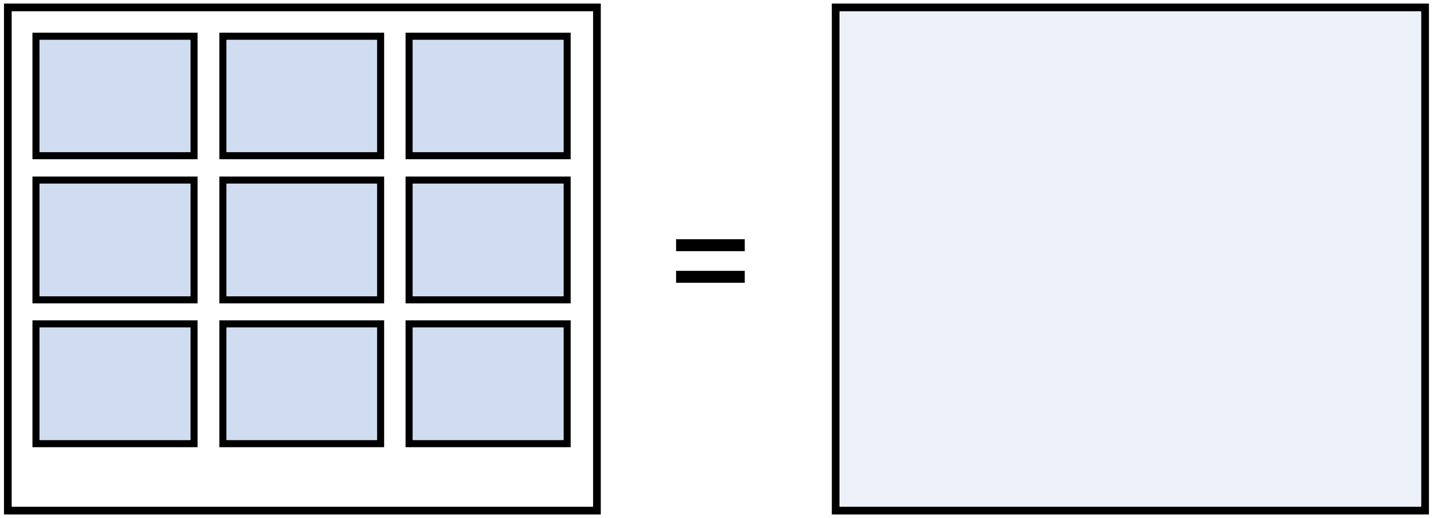
Mirror Boundary Condition – Modern Context

- Appendix Note A-3.2.3.:
  - "based on the assumption that the exposing building faces of adjacent buildings are of similar size and configuration, and are equidistant from the shared property line. Where buildings are of different sizes, the smaller building may be subject to a higher heat flux in the event of a fire compared to the larger building"



Grey Radiator Approximation

- As a simplification, exposing the opening considered a "grey radiator":



- The "grey radiator" approximation is reasonable and approaches actual physics at increasing separation distances

Table Equation – Unsprinklered

$$\%\ openings = 100\frac{\phi_C}{\phi}$$

$$\phi_C = 0.07\ (A, C, D, F3)\ or\ 0.035\ (E, F1, F2)$$

Critical Configuration Factor Based on Occupancy

$$\phi = \frac{2}{\pi}\left\{\sqrt{\frac{\frac{A}{S}}{\frac{A}{S}+4}}\tan^{-1}\left[\sqrt{\frac{A\cdot S}{\frac{A}{S}+4}}\right]+\sqrt{\frac{A\cdot S}{A\cdot S+4}}\tan^{-1}\left[\sqrt{\frac{\frac{A}{S}}{A\cdot S+4}}\right]\right\}$$

$$A = \frac{h\cdot w}{d^2}$$

EBF

$$d = 2\cdot LD - 1.8288$$

Flame Front

$$S = \frac{h}{w}\ or\ \frac{w}{h}, whichever\ is\ greater$$

Ratio

Tables: Unsprinklered

Table 3.2.3.1.-B
Unprotected Opening Limits for a Building or Fire Compartment that is not Sprinklered Throughout
Forming Part of Article 3.2.3.1.

Exposing Building Face		Area of *Unprotected Opening* for Groups A, C, D, and F, Division 3 *Occupancies*, %																									
Max. Area, m²	Ratio (L/H or H/L)[1]	*Limiting Distance*, m																									
		0	1.2	1.5	2.0	2.5	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	25	30	35	40	45	50
10	Less than 3 : 1	0	8	10	18	29	46	91	100																		
	3 : 1 to 10 : 1	0	8	12	21	33	50	96	100																		
	over 10 : 1	0	11	18	32	48	68	100																			
15	Less than 3 : 1	0	7	9	14	22	33	63	100																		
	3 : 1 to 10 : 1	0	8	10	17	25	37	67	100																		
	over 10 : 1	0	10	15	26	39	53	87	100																		
20	Less than 3 : 1	0	7	9	12	18	26	49	81	100																	
	3 : 1 to 10 : 1	0	8	10	15	21	30	53	85	100																	
	over 10 : 1	0	9	14	23	33	45	72	100																		
25	Less than 3 : 1	0	7	8	11	16	23	41	66	98	100																
	3 : 1 to 10 : 1	0	8	9	13	19	26	45	70	100																	
	over 10 : 1	0	9	13	21	30	39	62	90	100																	
30	Less than 3 : 1	0	7	8	11	15	20	35	56	83	100																
	3 : 1 to 10 : 1	0	7	9	12	17	23	39	61	88	100																
	over 10 : 1	0	8	12	19	27	36	56	79	100																	
40	Less than 3 : 1	0	7	8	10	13	17	28	44	64	89	100															
	3 : 1 to 10 : 1	0	7	8	11	15	20	32	48	69	93	100															
	over 10 : 1	0	8	11	17	24	31	47	66	88	100																
50	Less than 3 : 1	0	7	8	9	12	15	24	37	53	72	96	100														
	3 : 1 to 10 : 1	0	7	8	10	14	18	28	41	57	77	100															
	over 10 : 1	0	8	10	15	21	28	41	57	76	97	100															

Table Equation - Sprinklered

$$\% \, openings = 100 \frac{\phi_C}{\phi}$$

$$\phi_C = 0.14 \, (A, B, C, D, F3) \; or \; 0.07 \, (E, F1, F2)$$

$$\phi = \frac{2}{\pi} \left\{ \sqrt{\frac{\frac{A}{3}}{\frac{A}{3} + 4}} \tan^{-1} \left[\sqrt{\frac{A \cdot 3}{\frac{A}{3} + 4}} \right] + \sqrt{\frac{A \cdot 3}{A \cdot 3 + 4}} \tan^{-1} \left[\sqrt{\frac{\frac{A}{3}}{A \cdot 3 + 4}} \right] \right\}$$

$$A = \frac{h \cdot w}{d^2}$$

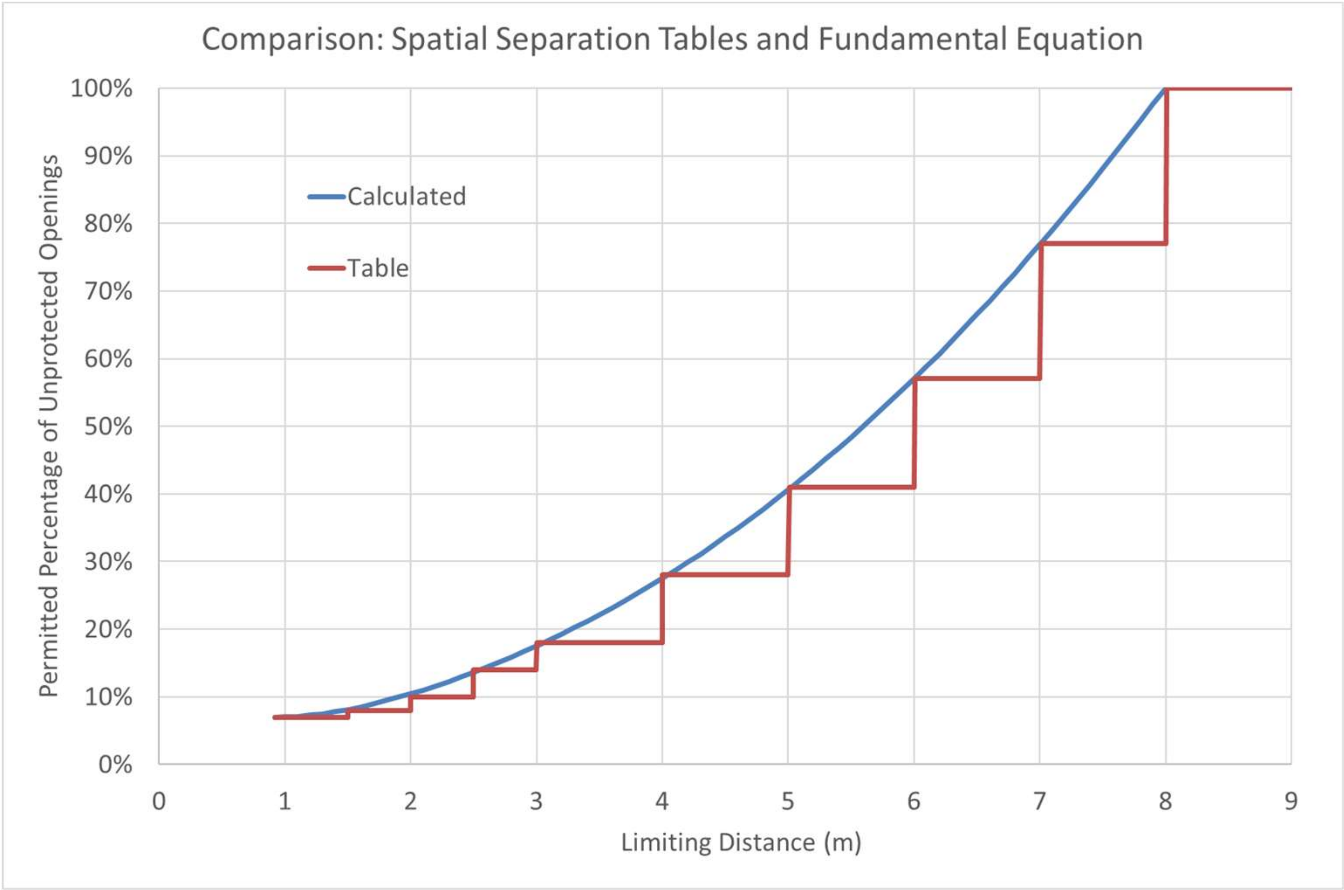
$$d = 2 \cdot LD - 1.8288$$

Tables: Sprinklered

Table 3.2.3.1.-D
Unprotected Opening Limits for a Building or Fire Compartment that is Sprinklered Throughout
Forming Part of Sentence 3.1.6.9.(5) and Article 3.2.3.1.

Exposing Building Face	Area of *Unprotected Opening* for Groups A, B, C, D and F, Division 3 *Occupancies*, %											
Max. Area, m²	*Limiting Distance*, m											
	0	1.2	1.5	2.0	2.5	3	4	5	6	7	8	9
10	0	16	24	42	66	100						
15	0	16	20	34	50	74	100					
20	0	16	20	30	42	60	100					
25	0	16	18	26	38	52	90	100				
30	0	14	18	24	34	46	78	100				
40	0	14	16	22	30	40	64	96	100			
50	0	14	16	20	28	36	56	82	100			
60	0	14	16	20	26	32	50	72	98	100		
80	0	14	16	18	22	28	42	58	80	100		
100	0	14	16	18	22	26	36	50	68	88	100	
150 or more	0	14	14	16	20	22	30	40	52	66	82	100

Interpolation



Concentration of Openings

Opening Clustering

- “Grey radiator” approximation breaks down where unprotected openings are clustered and at short separation distances

$$\text{Area} = 0.24\ (2 \times \text{LD} - 1.2)^2$$

Limiting Distance, m	Maximum Area of Individual *Unprotected Openings*, m^2
1.2	0.35
1.5	0.78
2.0	1.88

6) The spacing between individual *unprotected openings* described in Sentence (5) that serve a single room or space described in Sentence (7) shall not be less than

a) 2 m horizontally of another *unprotected opening* that is on the same *exposing building face* and serves the single room or space, or

b) 2 m vertically of another *unprotected opening* that serves the single room or space, or another room or space on the same *storey*.

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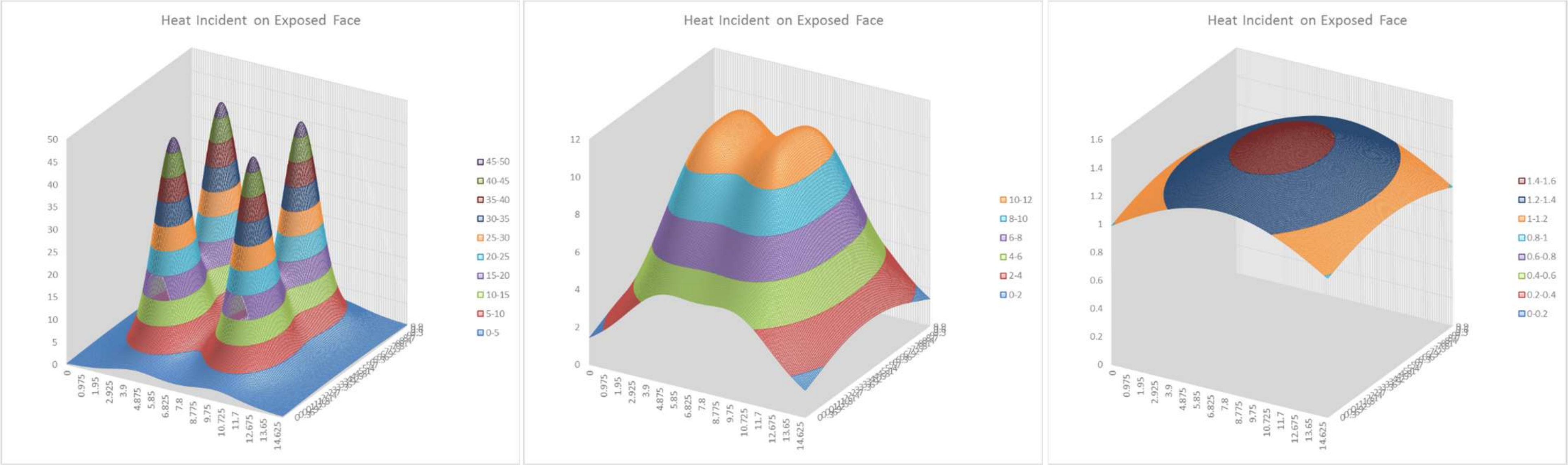
FIRE SCIENCE & ENGINEERING

Impact of Clustered Openings on Radiant Heat

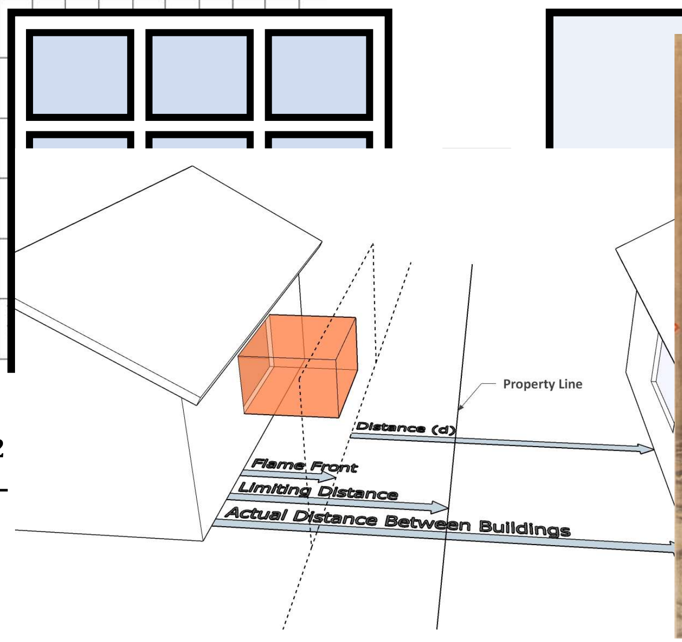


Key Takeaways

- The spatial separation Code requirements are based on science
- Still include assumptions, approximations, and simplifications
- Important to understand these when defining comfortable boundaries
- Examples of assumptions/simplifications:
  - Based on one test
  - High winds on test day
  - Pressed paperboard interior lining accelerated fire spread
  - Flashover reached in ~5 minutes
  - Wind direction and crib location created ideal cross-ventilation

Final Thoughts

Exposing Building Face		Area of *Unprotected Opening* for Groups A, C, D, and F, Division 3 *Occupancies*, %																			
Max. Area, m²	Ratio (L/H or H/L)(1)	*Limiting Distance*, m																			
		0	1.2	1.5	2.0	2.5	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20
10	Less than 3 : 1	0	8	10	18	29	46	91	100												
	3 : 1 to 10 : 1	0	8	12	21	33	50	96	100												
	over 10 : 1	0	11	18	32	48	68	100													
15	Less than 3 : 1	0	7	9	14	22	33	63	100												
	3 : 1 to 10 : 1	0	8	10	17	25	37	67	100												
	over 10 : 1	0	10	15	26	39	53	87	100												
20	Less than 3 : 1	0	7	9	12	18	26	49	81	100											
	3 : 1 to 10 : 1	0	8	10	15	21	30	53	85	100											
	over 10 : 1	0	9	14	23	33	45	72	100												
25	Less than 3 : 1	0	7	8	11	16	23	41	66	98	100										
	3 : 1 to 10 : 1	0	8	9	13	19	26	45	70	100											
	over 10 : 1	0	9	13	21	30	39	62	90	100											
30	Less than 3 : 1	0	7	8	11	15	20	35	56	83	100										
	3 : 1 to 10 : 1	0	7	9	12	17	23	39	61	88	100										
	over 10 : 1	0	8	12	19	27	36	56	79	100											
	Less than 3 : 1	0	7	8	10	13	17	28	44	64	89										
40	3 : 1 to 10 : 1	0	7	8	11	15	20	32	48	69	93										
	over 10 : 1	0	8	11	17	24	31	47	66	88	100										



$$\phi_C = \frac{\dot{q}''}{E} = \frac{12.5\ kW/m^2}{356\,kW/m^2}$$

Thank you!

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