

# Acceptable Performance – What is it?

Building Officials Association of BC  
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- Jeremy Bender is a Project Consultant with expertise in building code compliance, regulatory analysis, and technical building code training development and delivery of technical training for building professionals across Canada.



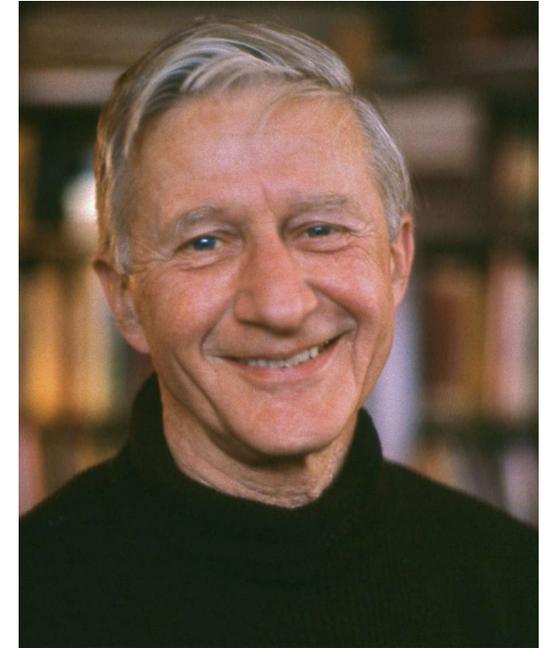
- Keith Calder is a professional engineer with over 25 years of experience in fire protection engineering. He has practiced across Canada and internationally with experience in complex forensic matters, extensive fire and egress modelling, in-depth building and fire code analysis, and detailed risk assessment.

# Overview

- Acceptable performance of alternative solutions under the Code
- Using the comparative approach to show equivalence
- Example: spatial separation (building on last week's session)
- Understanding risk and the intent of performance requirements

*“Despite the higher factor of safety in larger buildings it is the practice in many building bylaws to take further precautions by restricting the combustibile load and requiring nonbearing partitions, interior trim and even furniture to be non-combustible and **sometimes sprinklers are required on top of all this.***

*To the author of this paper this appears to be a malpractice. The correct way to regulate is to assess the risk and apply regulations accordingly. It should be unnecessary as a sequel to apply further requirements to diminish the risk. If it is necessary, these further regulations should have been considered as part of the initial risk.”*



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

# Level of Performance

## 1.2.1.1. Compliance with this Code

- 1) Compliance with this Code shall be achieved by
  - a) complying with the applicable acceptable solutions in Division B (see Note A-1.2.1.1.(1)(a)), or
  - b) except as required by Sentence (3), using alternative solutions, accepted by the *authority having jurisdiction* under Section 2.3. of Division C, that will achieve at least the **minimum level of performance required by Division B** in the areas defined by the objectives and functional statements attributed to the applicable acceptable solutions (see Note A-1.2.1.1.(1)(b)).

# Performance/Acceptable Risk

## **A-1.2.1.1.(1)(b) Compliance Via Alternative Solutions.**

Where a design differs from the acceptable solutions in Division B, then it should be treated as an “alternative solution”. A proponent of an alternative solution must demonstrate that the alternative solution addresses the same issues as the applicable acceptable solutions in Division B and their attributed objectives and functional statements. However, because the objectives and functional statements are entirely qualitative, demonstrating compliance with them in isolation is not possible.

Therefore, Clause 1.2.1.1.(1)(b) identifies the principle that Division B establishes the quantitative performance targets that alternative solutions must meet. In many cases, these targets are not defined very precisely by the acceptable solutions - certainly far less precisely than would be the case with a true performance code, which would have quantitative performance targets and prescribed methods of performance measurement for all aspects of building performance. Nevertheless, Clause 1.2.1.1.(1)(b) makes it clear that an effort must be made to demonstrate that an alternative solution will perform as well as a design that would satisfy the applicable acceptable solutions in Division B - not “well enough” but “as well as”. In this sense, it is Division B that defines the boundaries between acceptable risks and the “unacceptable” risks referred to in the statements of the Code’s objectives, i.e. the risk remaining once the applicable acceptable solutions in Division B have been implemented represents the residual level of risk deemed to be acceptable by the broad base of Canadians who have taken part in the consensus process used to develop the Code.

# Acceptable Performance/Risk

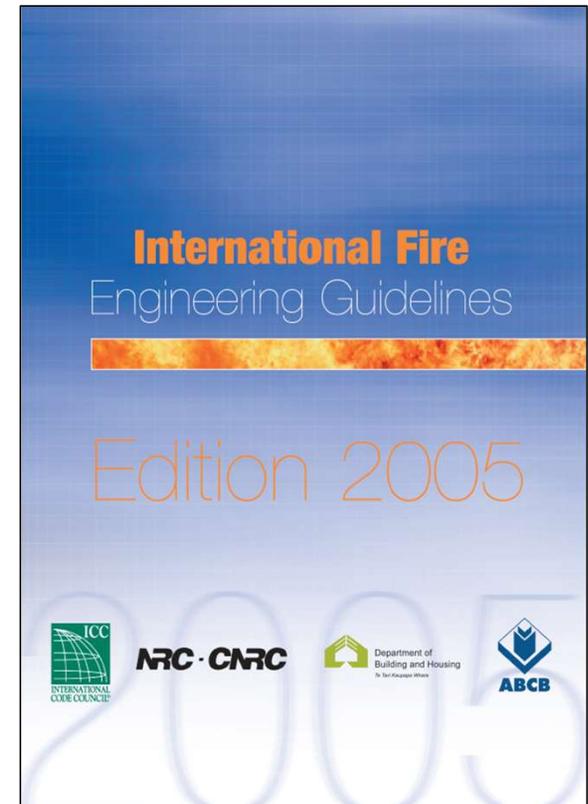
## Level of Performance

Where Division B offers a choice between several possible designs, it is likely that these designs may not all provide exactly the same level of performance. Among a number of possible designs satisfying acceptable solutions in Division B, the design providing the lowest level of performance should generally be considered to establish the minimum acceptable level of performance to be used in evaluating alternative solutions for compliance with the Code.

- Therefore: The performance of an alternative solution design should be compared to the performance of **any design** that complies with the acceptable solution(s) in Division B.

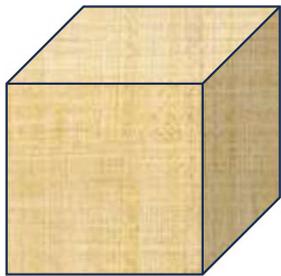
# Approaches to Evaluating Alternative Solutions

- Two recognized approaches:
  - **Absolute approach**
  - **Comparative approach**
- Guidance from the *International Fire Engineering Guidelines (IFEG)*
- NRC was directly involved in IFEG development
- Widely used internationally by fire engineers

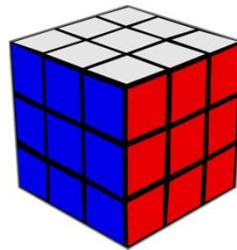


# Comparative Approach

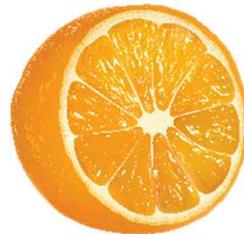
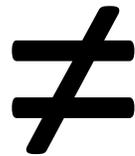
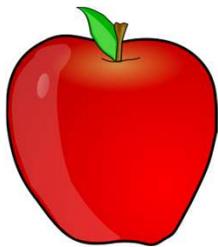
- How? – Good question – There is no clear guidance



Division B  
Compliant Design



Alternative Design



Both are cubes, but:

- The compliant cube is grey and the alternative cube is colourful
- The compliant cube does not have rotating parts, and the alternative cube does
- Etc.
- Depends on the characteristics that are key to the intended performance of the design - these are the things that should be compared

# Performance

## 3.2.3.1. Limiting Distance and Area of Unprotected Openings

- (1) Except as permitted by Articles 3.2.3.10. to 3.2.3.12., the area of *unprotected openings* in an *exposing building face* for the applicable *limiting distance* shall be not more than the value determined in accordance with
- (a) Table 3.2.3.1.-B or Table 3.2.3.1.-C for an *exposing building face* conforming to Article 3.2.3.2. of a *building or fire compartment* which is not *sprinklered*, or
  - (b) Table 3.2.3.1.-D or Table 3.2.3.1.-E for an *exposing building face* conforming to Article 3.2.3.2. of a *sprinklered fire compartment* that is part of a *building* which is *sprinklered* in conformance with Section 3.2.

3.2.3.1.	Limiting Distance and Area of Unprotected Openings
(1), (5), (6), (8) to (10)	[F03-OP3.1]

**F03** To retard the effects of fire on areas beyond its point of origin.

### OP3 Protection of Adjacent Buildings from Fire

An objective of this Code is to limit the probability that, as a result of the design or construction of the building, adjacent buildings will be exposed to an unacceptable risk of damage due to fire. The risks of damage to adjacent buildings due to fire addressed in this Code are those caused by—

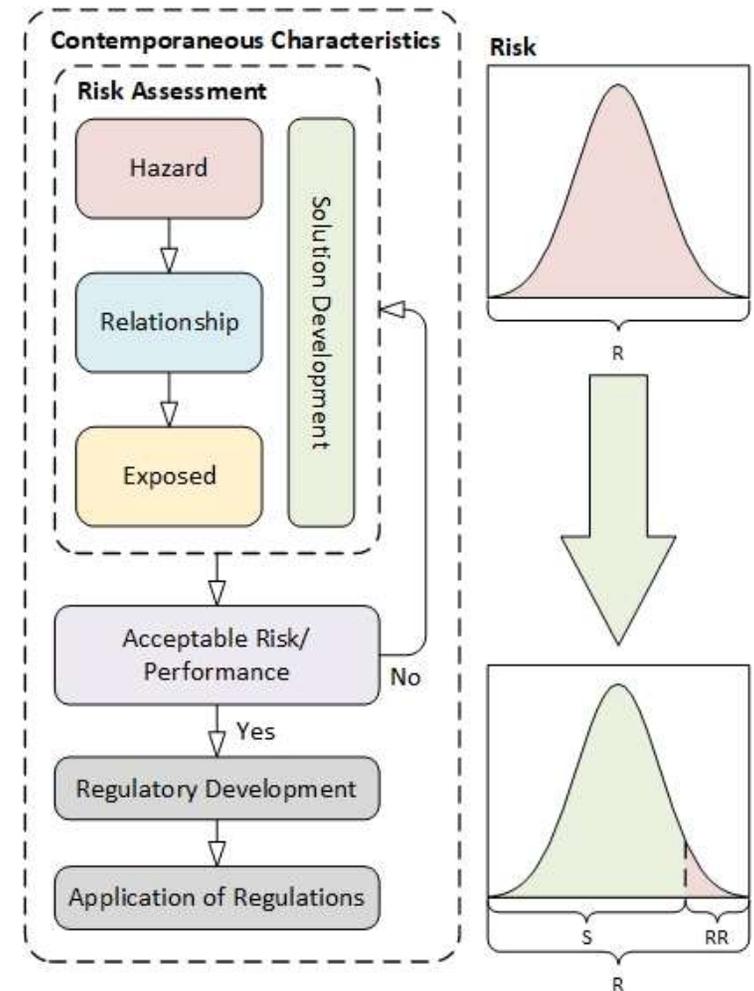
**OP3.1** – fire or explosion impacting areas beyond the building of origin

# What is Risk?

- Meacham: The possibility of an unwanted outcome in an uncertain situation, where the possibility of the unwanted outcome is a function of three factors:
  1. loss or harm to something that is valued,
  2. the event or hazard that may occasion the loss or harm, and
  3. a judgement about the likelihood that the loss or harm will occur.
- Spatial Separation Intent Statement:
  - To **limit the probability [Factor 3]** of the **spread of fire from the building to an adjacent building [Factor 2]** during the time required for emergency responders to perform their duties, which could lead to **damage to adjacent buildings [Factor 1]**

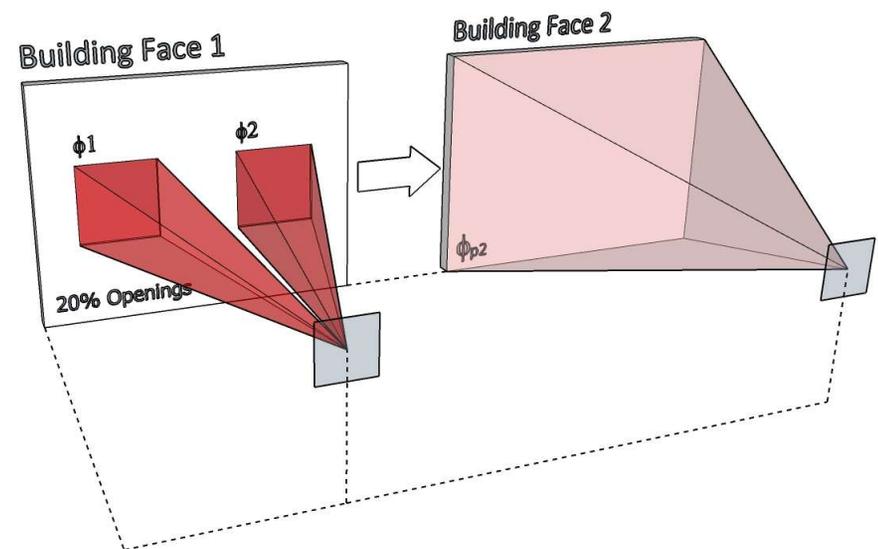
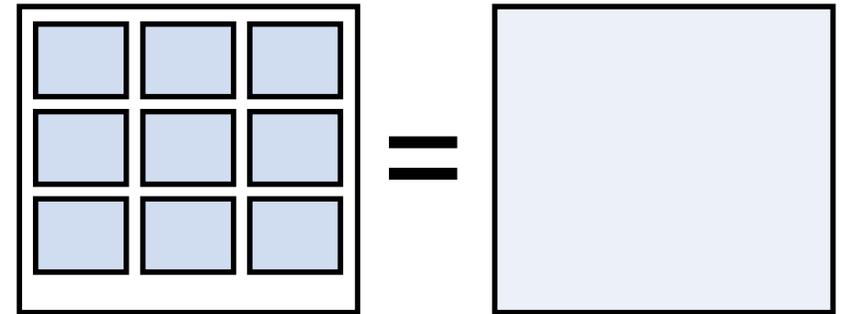
# Example: Spatial Separation Regulatory Risk Paradigm

- Hazard: Fire area with a specific emissive power (fire service arrival time assumed)
  - 178 kW/m<sup>2</sup> for low hazard
  - 356 kW/m<sup>2</sup> for high hazard
- Exposed: Adjacent building with wood-based construction
  - 12.5 kW/m<sup>2</sup> for pilot ignition
- Relationship between hazard and exposed
  - Configuration factor with grey radiator approximation



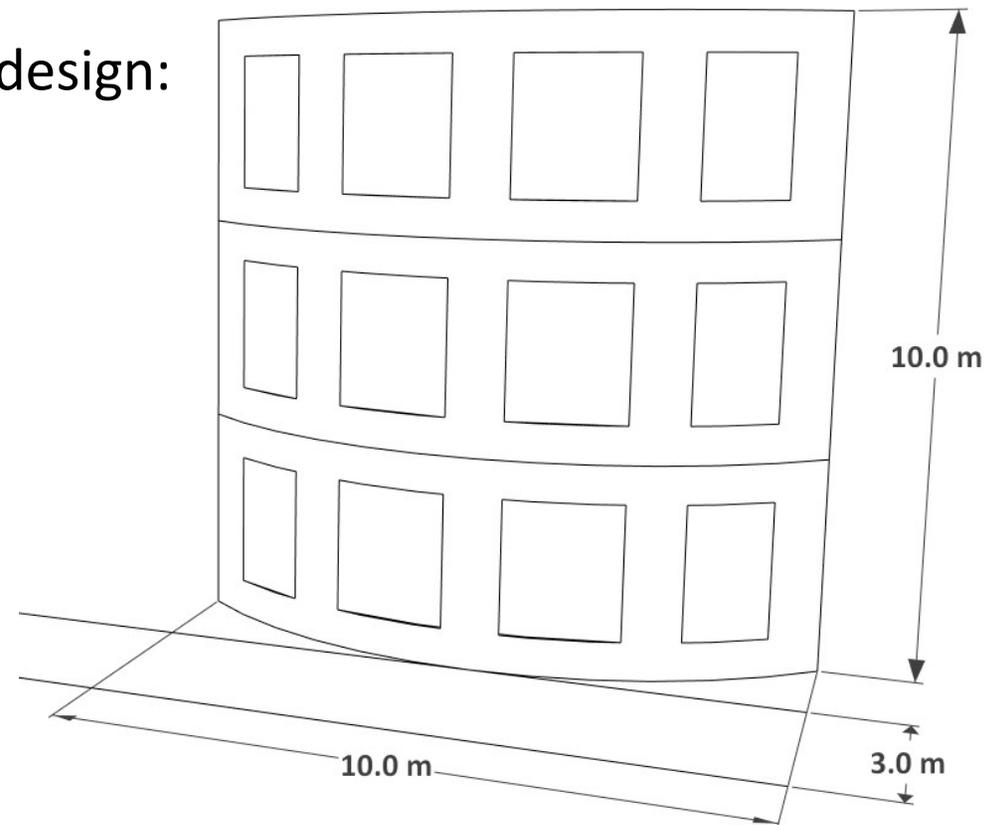
# Example: Spatial Separation Grey Radiator

- Where does the comparative approach break down?
- Consider the grey radiator approximation:
  - All openings are simplified into a single plane
  - This approximation is not very good at lower percentages of unprotected openings, and where the openings are clustered together
  - Regardless – still a compliant design



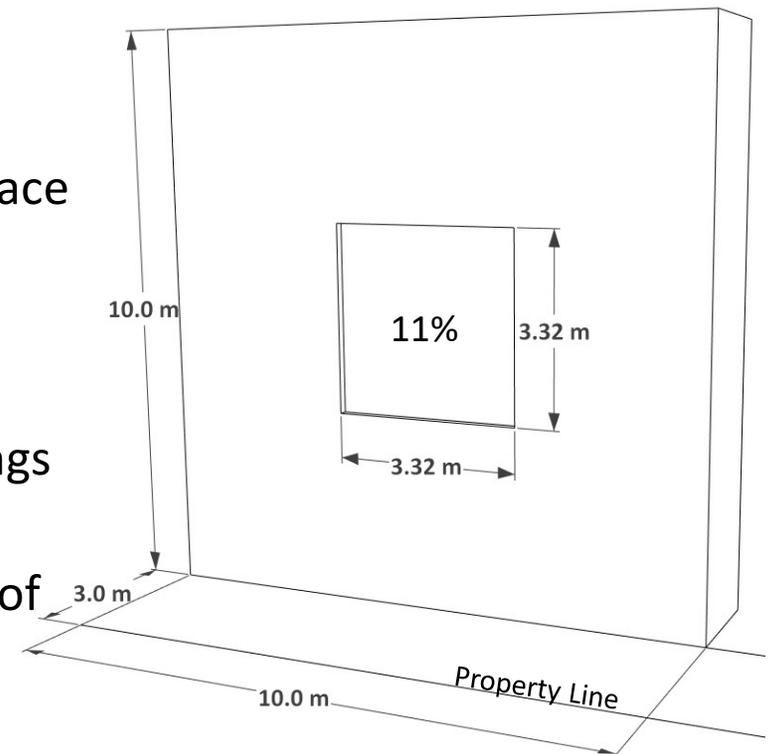
# Example: Spatial Separation Alternative Design

- Consider the following alternative design:
  - Office occupancy
  - Unsprinklered
  - Building width = 10 m
  - Building height = 10 m (3 storeys)
  - Limiting distance = 3 m
  - Curved exterior wall
- Applicable requirements:
  - Sentence 3.2.3.1.(1)
  - Table 3.2.3.1.-B
  - Sentence 3.2.3.2.(1)



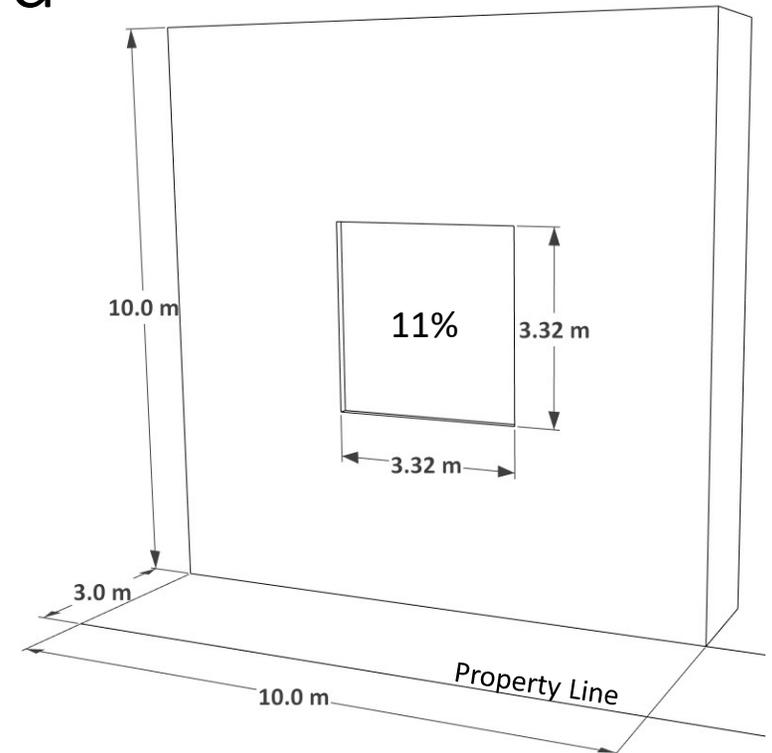
# Example: Spatial Separation Comparative Approach

- Acceptable solution performance:
  - Sentence 3.2.3.2.(1) permits use of full building face
  - Exposing building face area = 100 m<sup>2</sup>
  - Exposing building face ratio = 1:1
  - Limiting distance = 3 m
  - Table 3.2.3.1.-B permits 11% unprotected openings
  - 11% of 100 m<sup>2</sup> is 11 m<sup>2</sup>
  - An opening that is 3.32 m by 3.32 m has an area of 11 m<sup>2</sup>
  - This unprotected opening can be placed at the centre of the wall



# Example: Spatial Separation Comparative Approach Cont'd

- Acceptable solution performance:
  - What is the calculated heat flux from this opening to a mirror boundary (i.e., 6 m from the opening)
  - Using the information that went into the development of the spatial separation tables:
    - Source emissive power =  $178 \text{ kW/m}^2$
    - Distance = 6 m
    - Flame front = 1.8288 m (6 ft)



# Example: Spatial Separation Level of Performance

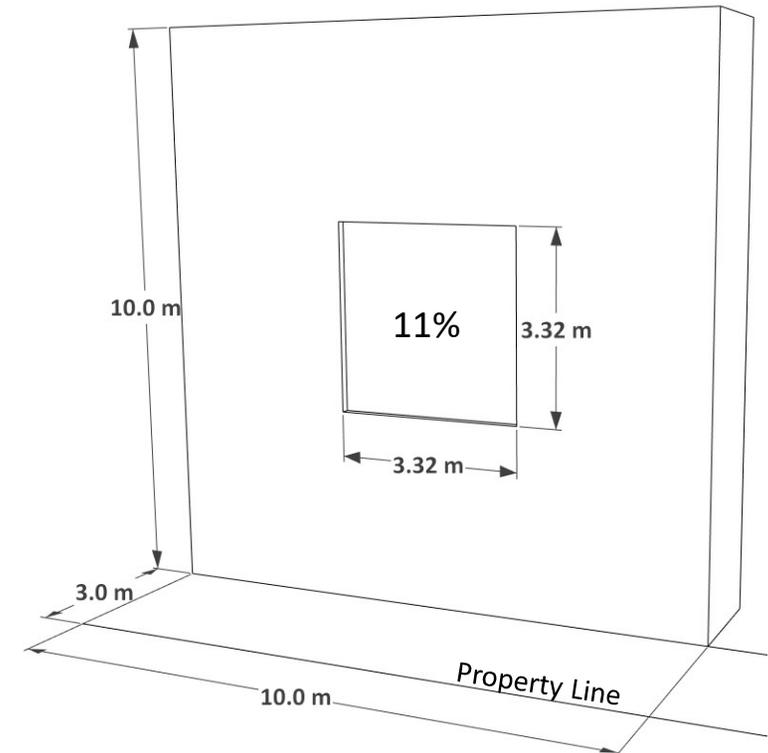
- Acceptable solution performance:
  - Heat flux calculation:  $\dot{q}'' = \phi \cdot E$
  - E = Emissive power (178 kW/m<sup>2</sup>)
  - $\phi$  = Configuration factor

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

$A = \frac{h \cdot w}{d^2}$  ← EBF

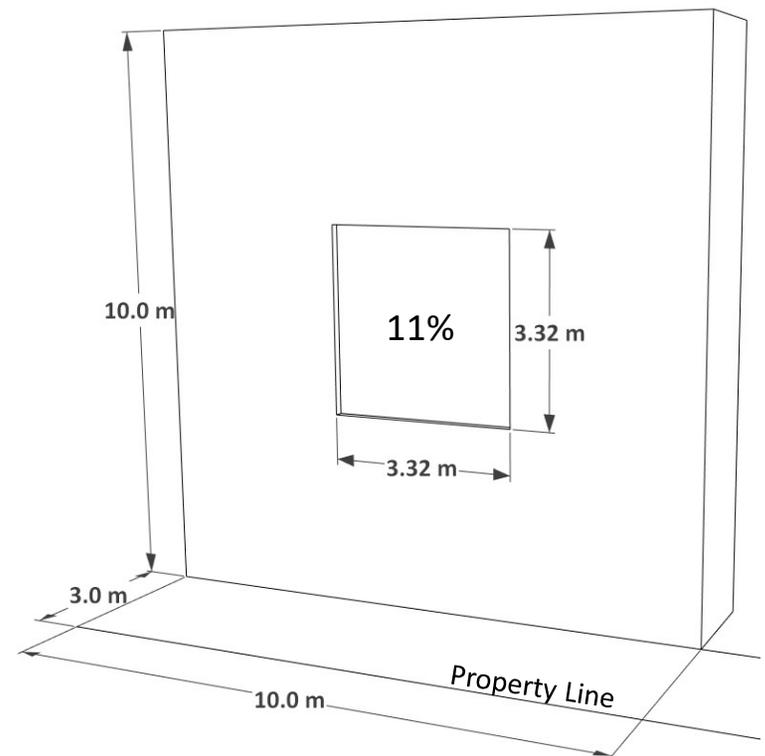
$d = 2 \cdot LD - 1.8288$  ← Flame Front

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



# Example: Spatial Separation Level of Performance Cont'd

- Acceptable solution performance:
  - Heat flux calculation:  $\dot{q}'' = \phi \cdot E$
  - E = Emissive power (178 kW/m<sup>2</sup>)
  - $\phi = 0.1665$
  - $\dot{q}'' = 0.1665 \times 178 \text{ kW/m}^2 = \mathbf{29.6 \text{ kW/m}^2}$
  - Recall that Autoignition of wood  $\sim 30 \text{ kW/m}^2$



# Science Break!

## National Institute of Standards and Technology, Fire Dynamics

Heat Flux (kW/m <sup>2</sup> )	Example
1	Sunny day
2.5	Typical firefighter exposure
3-5	Pain to skin within seconds
20	Threshold flux to floor at flashover
84	Thermal Protective Performance Test (NFPA 1971)
60 - 200	Flames over surface

# Example: Spatial Separation - Recall

- Div. A, Sentences 1.2.1.1.(1) and (2):
  - “the minimum level of performance required by the applicable acceptable solutions”
  - “the level of performance in respect of a functional statement refers to the performance of the functional statement as it relates to the objective”

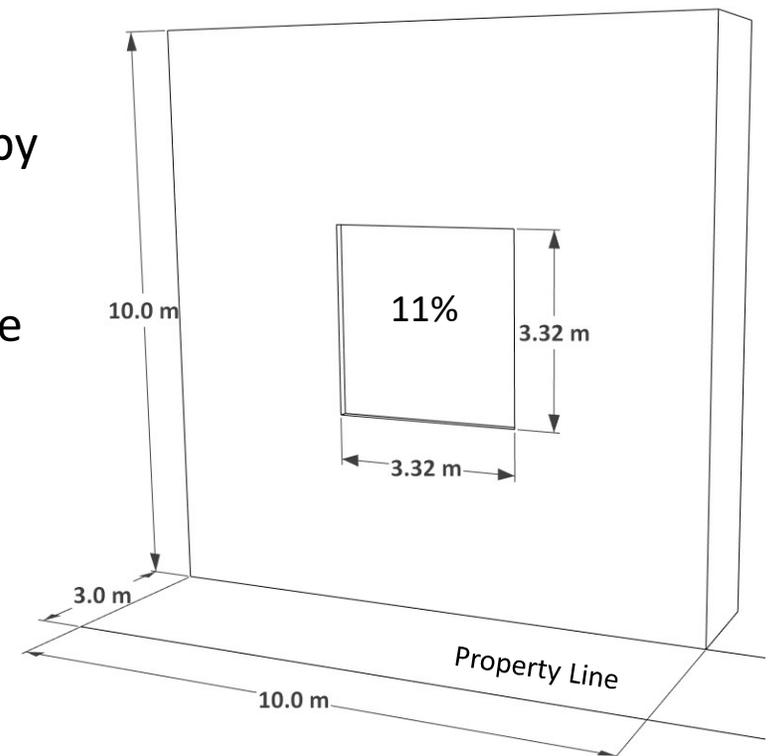
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OP3.1 – fire or explosion impacting areas beyond the *building* of origin

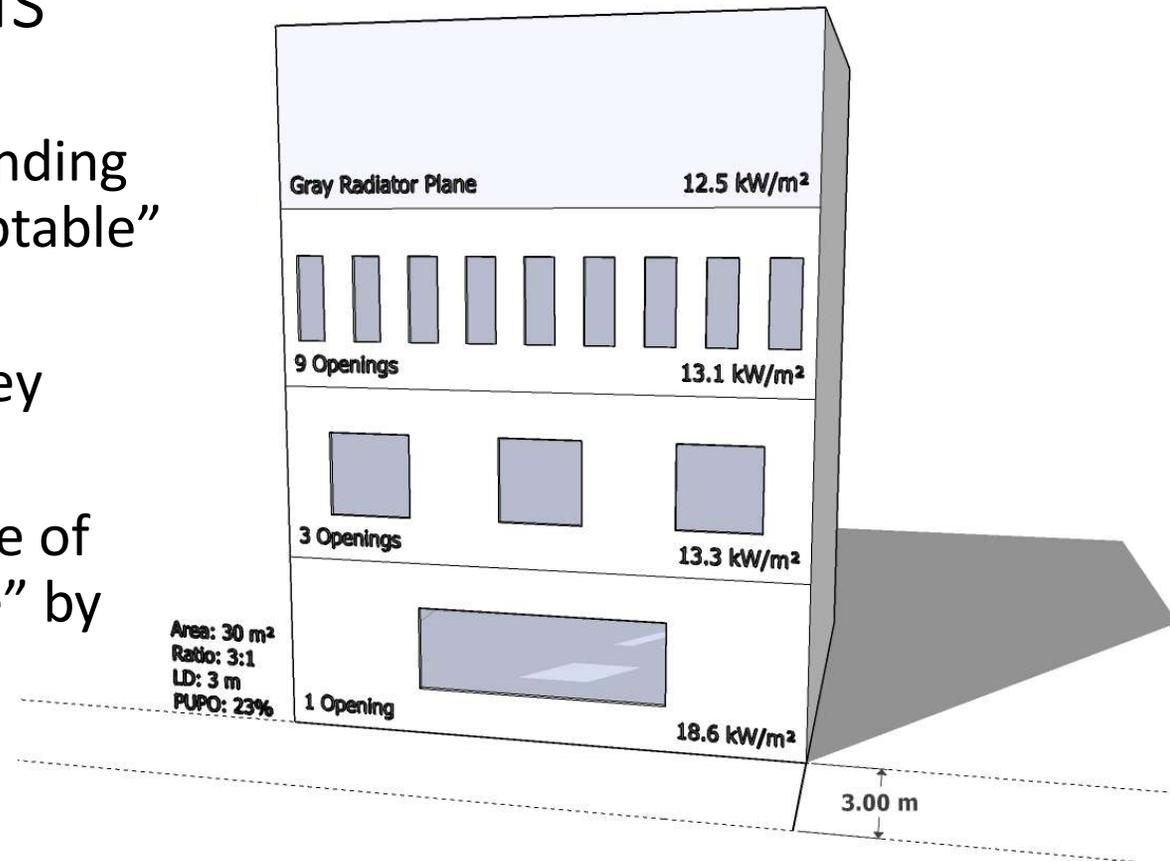
F03 To retard the effects of fire on areas beyond its point of origin.

- In this case **29.6 kW/m<sup>2</sup>**, which  $\neq$  **12.5 kW/m<sup>2</sup>**



# Example: Spatial Separation Acceptable Solutions

- Using this approach and depending on the values used, the “acceptable” incident heat flux can vary
- This is a direct result of the grey radiator approximation
- What is the extent of the range of values considered “acceptable” by the OBC?



**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.

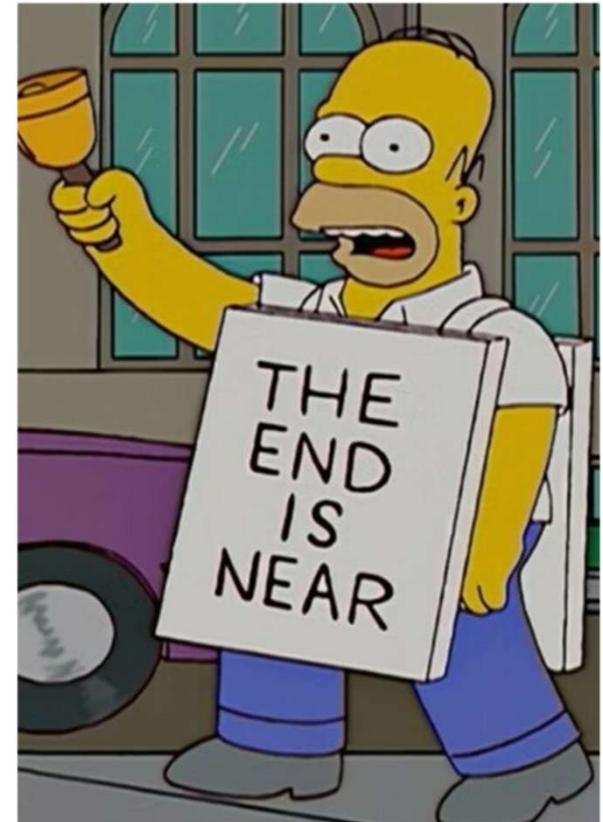
Exposing Building Face		Area of Unprotected Opening for Groups A, C, D, and F, Division 3 Occupancies, %																									
Max. Area, m <sup>2</sup>	Ratio (L/H or H/L) <sup>(1)</sup>	Limiting Distance, m																									
		0	1.2	1.5	2.0	2.5	3	4	5	6	7	8	9	10	11	12	13	14	16	18	20	25	30	35	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															

**Actual Spatial Separation Table**

8%	30%	10%	23%	46%	90%																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																		
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# Is the Sky Falling?

- No – things are not as bad as they seem
- Examples of assumptions/simplifications for spatial separation:
  - 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



# Other Examples

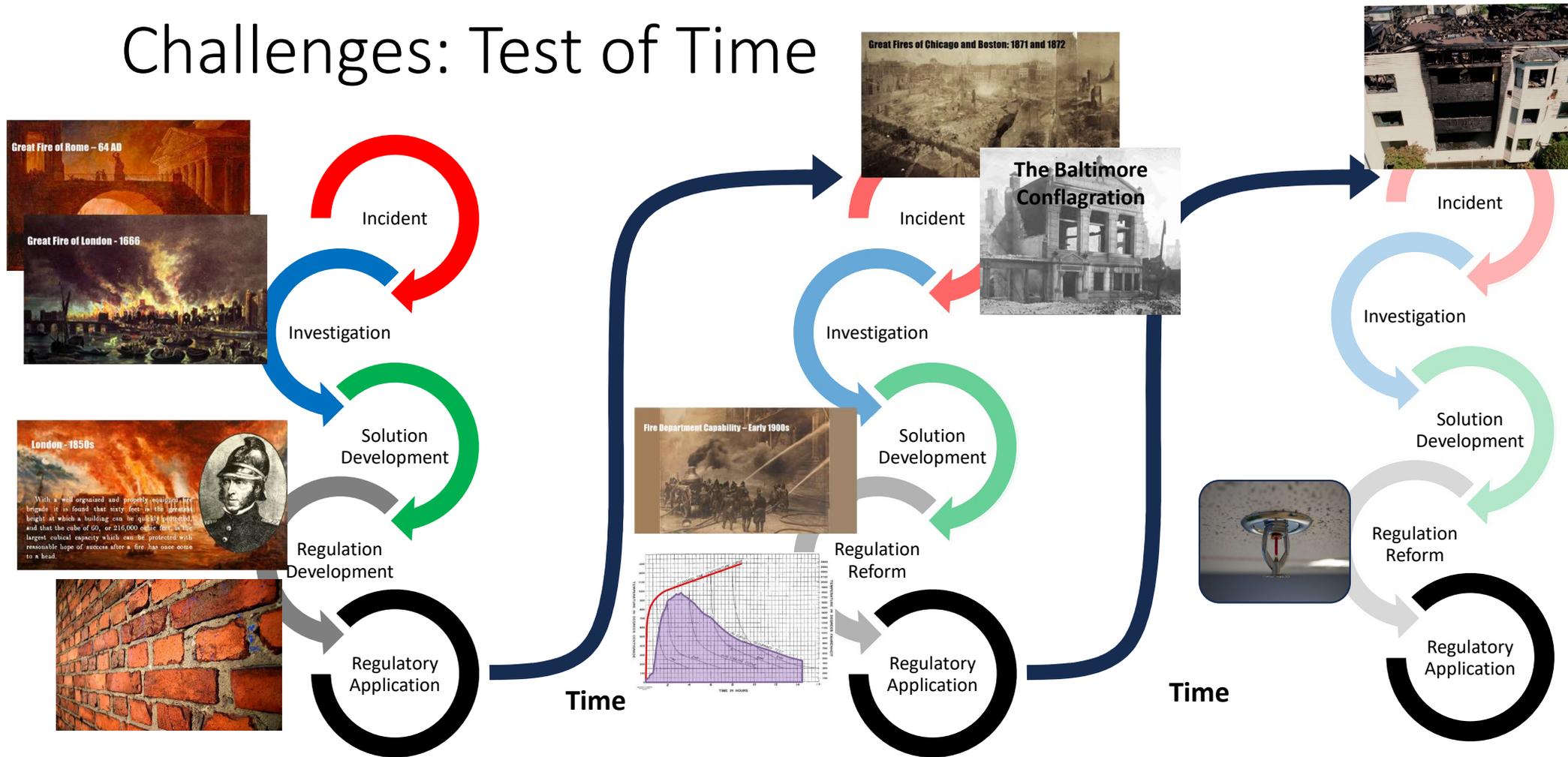
- Exposure protection – 3 m [Sentence 3.2.3.13.(2)]
- Combustible vs noncombustible construction using the worst-case noncombustible assembly as a comparison to allow combustible construction
- Sprinklers in general

Scenario	Description	Area of Openings	Maximum Incident Radiant Heat Flux	Distance from Plane of the Openings at Maximum
Scenario 1	Alternative Solution – Ground Floor	Window: 1.829 m × 1.829 m Door: 0.916 m × 2.632	27.9 kW/m <sup>2</sup>	3 m (1.2 m from flame front)
Scenario 2	Alternative Solution – Second Floor	Window: 1.831 m × 1.524 m	6.24 kW/m <sup>2</sup>	3 m (1.2 m from flame front)
Scenario 3	Acceptable Solution - Ground Floor	Window: 1.829 m × 1.829 m Door: 0.916 m × 2.632	106 kW/m <sup>2</sup>	3 m (1.2 m from flame front)

# Why Does This Approach Break Down?

- Acceptable solutions do not define a single level of performance (acceptable risk)
- Each requirement can fall within a **range of performance**
- Similar requirements may have **different ranges**
- Actual performance may differ from original intent
- Code development follows a **“test-of-time” approach**
  - Aim for the target → Only know how close we are after application
- Over time, **gradual changes can shift performance** away from the original intent

# Challenges: Test of Time

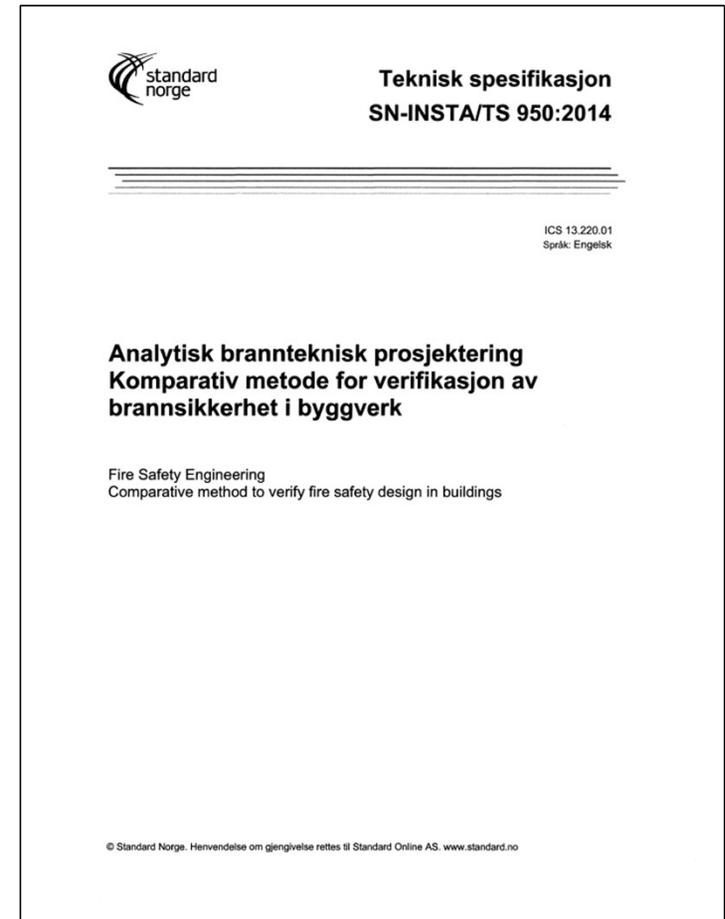


# Pot Roast Principle



# What Do Others Do?

- Denmark, Finland, Iceland, Norway and Sweden have a technical specification
- Reference design
  - “reference building shall be equivalent to the trial fire safety design building to ensure appropriate comparison”
  - “The reference building shall be of a design that may actually be constructed”
  - “All conditions, assumptions and simplifications shall be described and measured to ensure that they are reasonable and realistic”

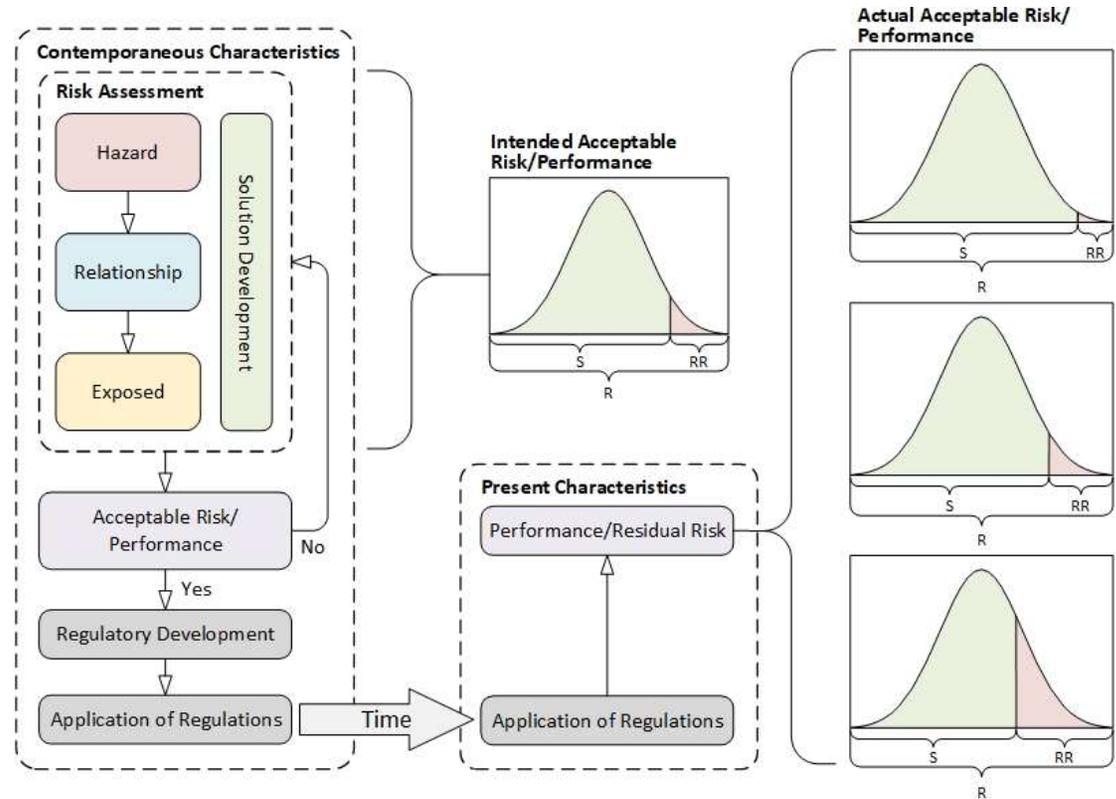


# What do we do?

- Know the fundamentals of the acceptable solution requirement(s)
- Know the characteristics that are key to the intended performance of the design
- Understand the underlying phenomena
- Know the acceptance criteria (if possible)
- Recall my presentation from last week for all of the above information

# Takeaways – Risk Over Time

- There is no single value of “acceptable risk” (acceptable performance) as defined in the OBC
- Acceptable risk can vary as a function of the specific design being considered
- Acceptable risk may not actually be acceptable



# Final Thoughts

*“The Magic numbers embodied in regulations are accepted without question, while any engineering solution is subject to a disproportionately high standard of proof. To move forward, rules need to have an engineering basis and to be goal-related: the purpose of rules needs to be understood by both researchers and regulators.”*

Margaret Law and Paula Beever - 1995



# Thank you!

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