THE HONG KONG INSTITUTION OF ENGINEERS 香港工程師學會

香港檢測和認證局 The Hong Kong Council for Testing and Certification

香港認可處 Hong Kong Accreditation Service

Seminar on Testing and Certification for Fire Safety in Buildings -

Testing Methods and Requirements for Fire Performance of Curtain Wall Systems

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Date: 19 October 2016

Agenda

Section 1:	Fire Resistance Tests on Curtain Walling Systems
Section 2:	Smoke Control Tests on Smoke Barrier at the Void Between the Façade and Floor Slab
Section 3:	Common issue on Tests for Curtain Walling Systems
Section 4:	Q &A

Section 1

Fire Resistance Tests on Curtain Walling Systems

What and Why is a standard test?

- **Standardized test with repeatable testing condition (heating curve, pressure, etc.) e.g. BS EN 1364-3 – Fire Resistance Tests for Non-loadbearing elements: Curtain walling – Full Configuration (Complete assembly)**

- **Standardized pass/fail criteria to compare same types of products**

- **Limitation:**
  - **The test only gives information about the performance of the product under specific test conditions and specific design**
  - **The test results only applicable to the specimens that was tested**
  - **The result may not reflect the real situation in practice**
    - **Different from some mechanical test like tension force of re-bar (test on material vs test on system)**
  - **Every fire in real practice are different**
    - **The location of fire, close to the door or remote from the door cause significant difference**

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Heating Curve

- **Real Compartment Fire**

- **How long the Growth Period and the Fully Development Phase last for?**

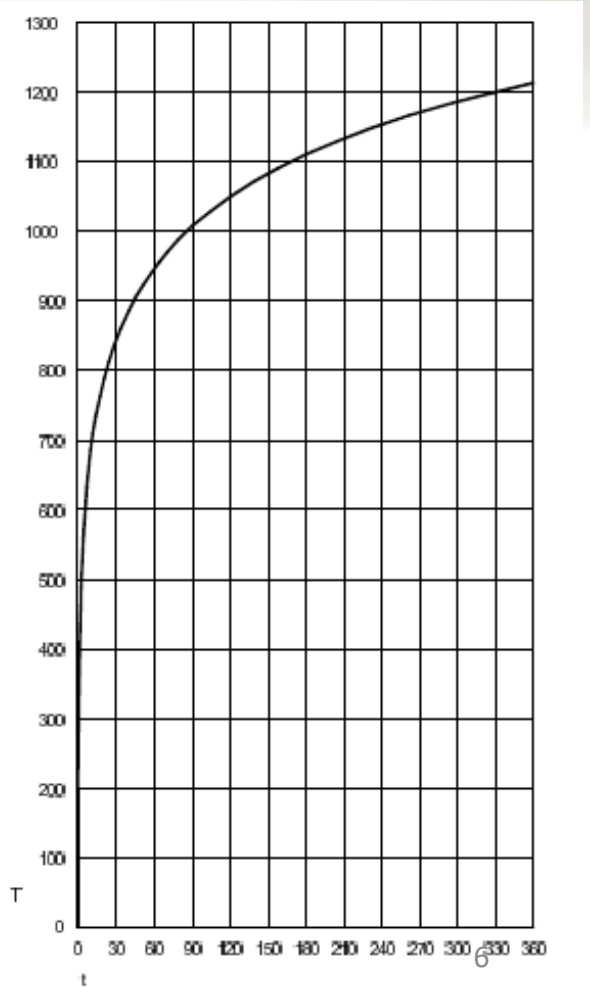
Heating Curve (Cont.)

- **Heating Curve Use in Fire Test**
  - **Expression:**

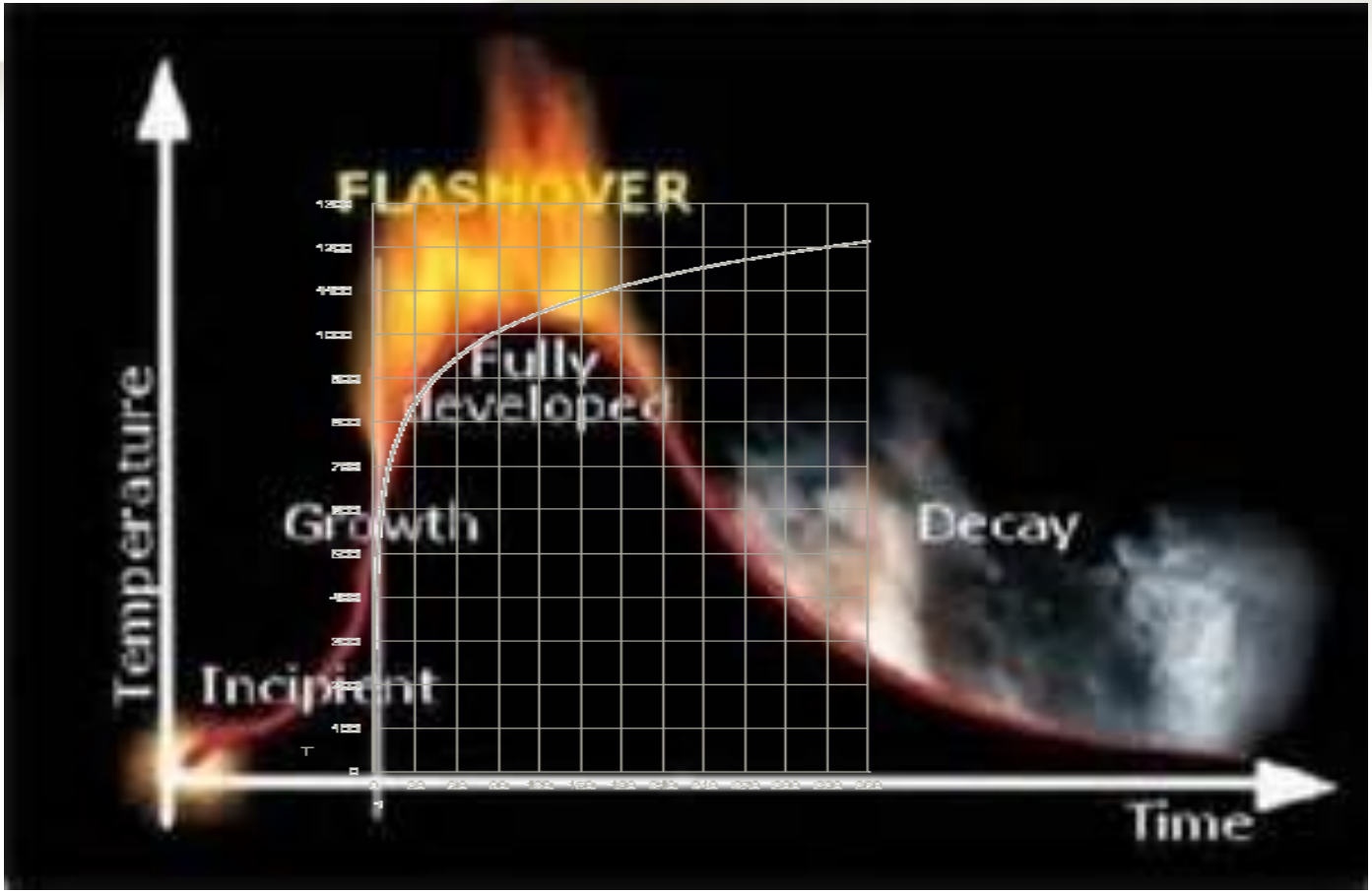
    $T = 345 \log_{10}(8t + 1) + 20$

    - ***T*** **is the average temperature in furnace (°C)**
    - ***t*** **is the time, in minute**
  - **Same for BS 476 and BS EN 1363**

Time (min)	Temp (°C)
30	842
60	945
90	1006
120	1049
180	1110
240	1153
360	1214



A Very Conservative Testing Condition?



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BS EN 1363-2: External Fire Exposure Curve

5 External fire exposure curve

5.1 General

EN 1363-1 defines the heating conditions, in terms of a specified temperature-time relationship, for the determination of fire resistance.

In some cases elements may be exposed to conditions which are less severe than when the element or structure is exposed to a compartment fire. Examples of this are walls at the perimeter of a building which may be exposed to an external fire or flames coming out of windows. There is also a need to ensure that the nature of fire protection is such that the re-entry of the fire into the building is prevented. Because of the nature of external fire with the additional possibilities for heat dissipation, a lower level of heat exposure is given.

This exposure condition is only relevant to the assessment of the fire resistance of separating elements. Other evaluation techniques exist for the evaluation of beams and columns and for measuring external fire spread.

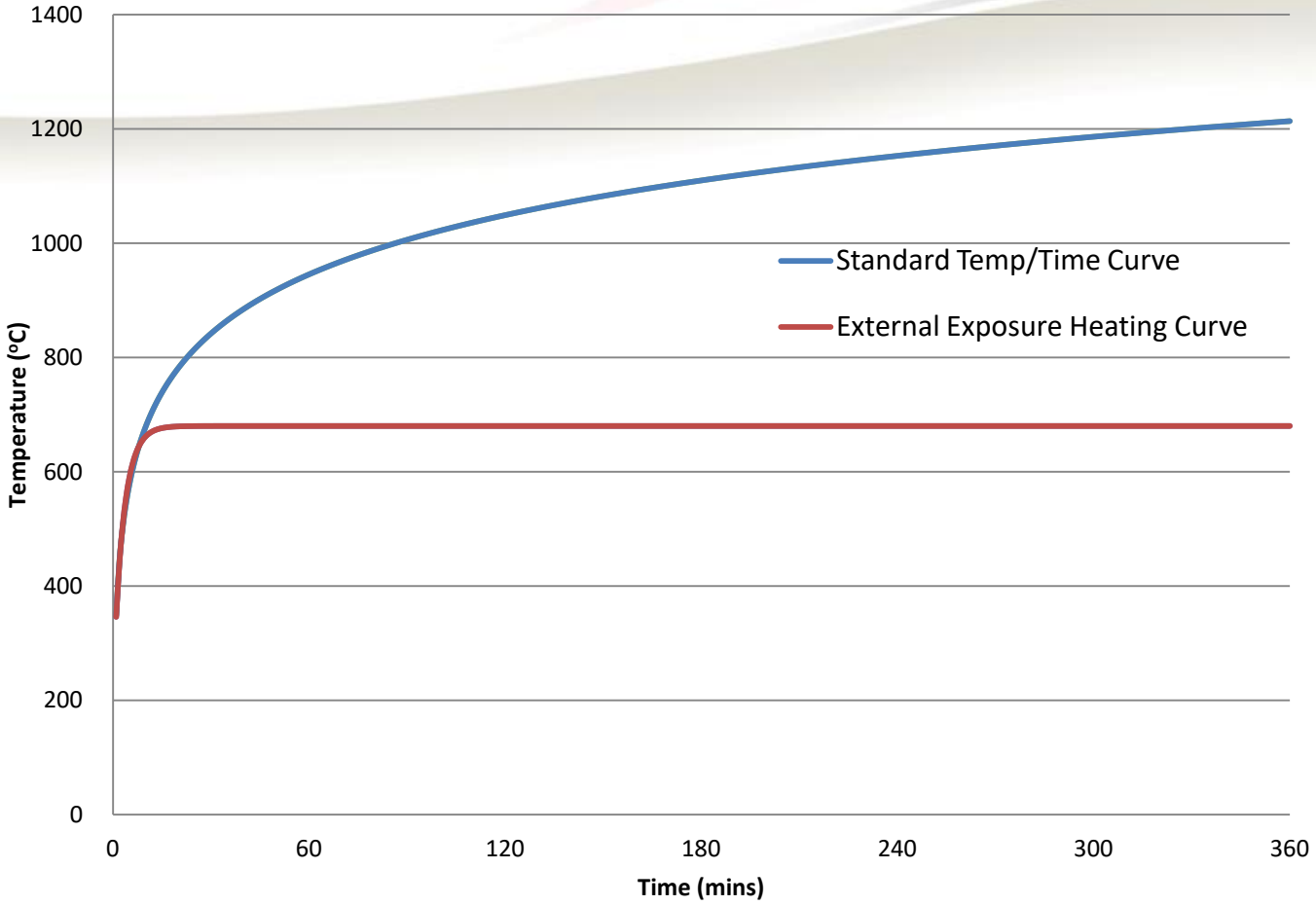
Where there is an identified requirement for such a fire exposure, the following external fire exposure curve shall be used.

5.2 Expression of temperature-time curve

A temperature-time curve to be designated as the external fire exposure curve shall be defined by the following expression.

$$T = 660\ [1 - 0{,}687\, e^{-0{,}32t} - 0{,}313\, e^{-3{,}8t}] + 20$$

External Fire Exposure Curve



Time (min)	Standard (°C)	External (°C)
1	349	346
2	445	441
3	502	506
4	544	554
5	576	588
6	603	614
7	626	632
8	645	645
9	663	655
10	678	662
20	781	679
30	842	680
40	885	680
50	918	680
60	945	680
70	968	680
80	988	680
90	1006	680
100	1022	680
110	1036	680
120	1049	680

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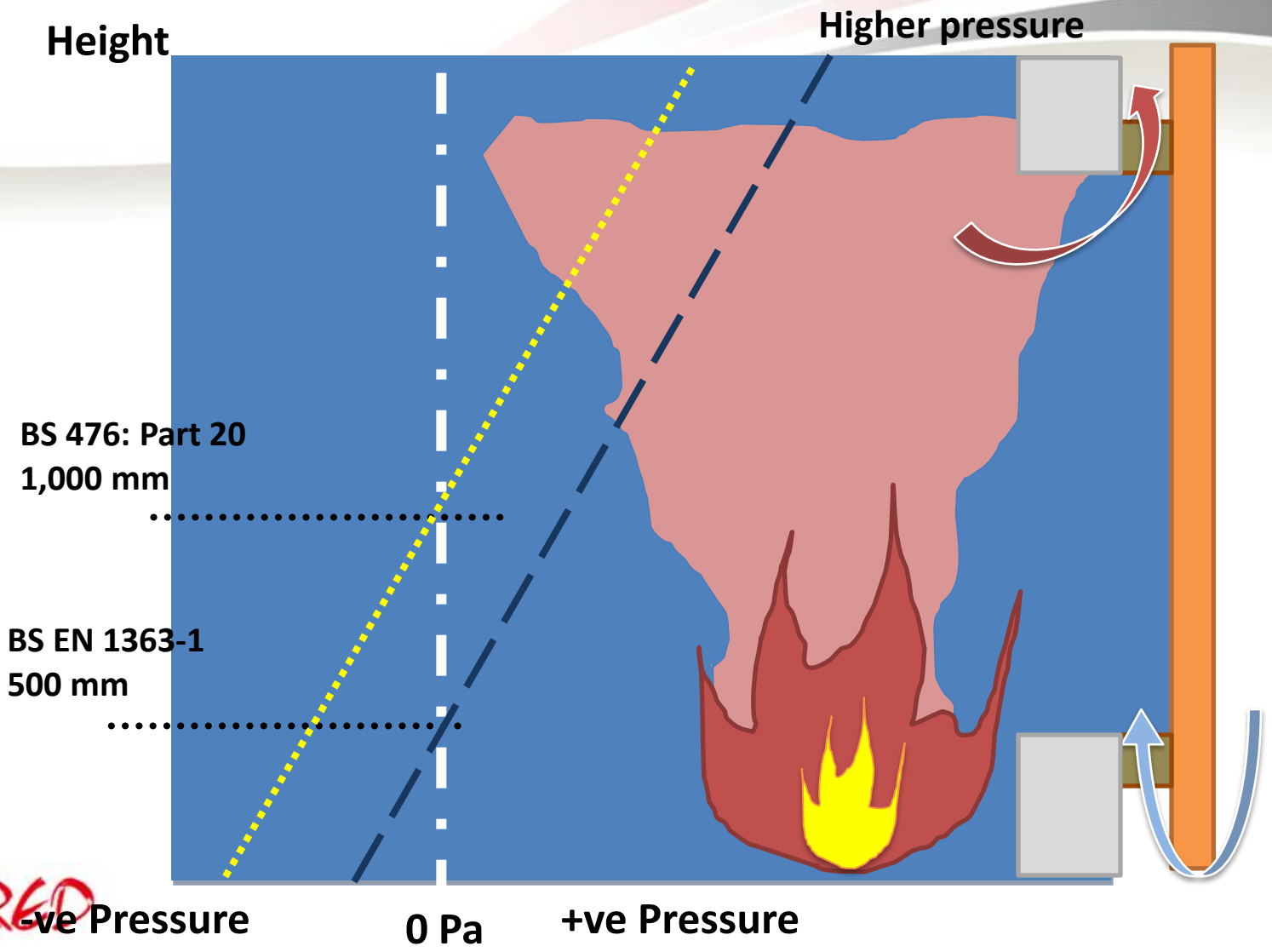
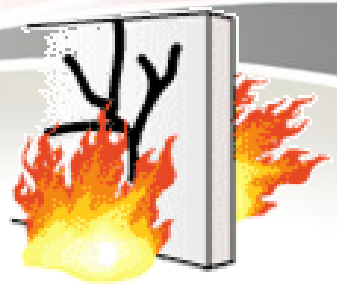
Fire Test Furnace

Inside Furnace



Performance Criteria

- **Integrity performance**
  - **The ability of the specimen to prevent the passage of flames and hot gases through it and to prevent the occurrence of flame on the unexposed side**



Integrity

- **Insulation performance**
  - **The ability of a specimen to restrict the temperature rise of the unexposed face to below specific level**

Insulation

- **Loadbearing capacity**
  - **The ability of a specimen intended to bear external loading to support its load, without exceeding specified criteria with respect to both the extent of, and rate of deflection**

Load Bearing

Integrity performance

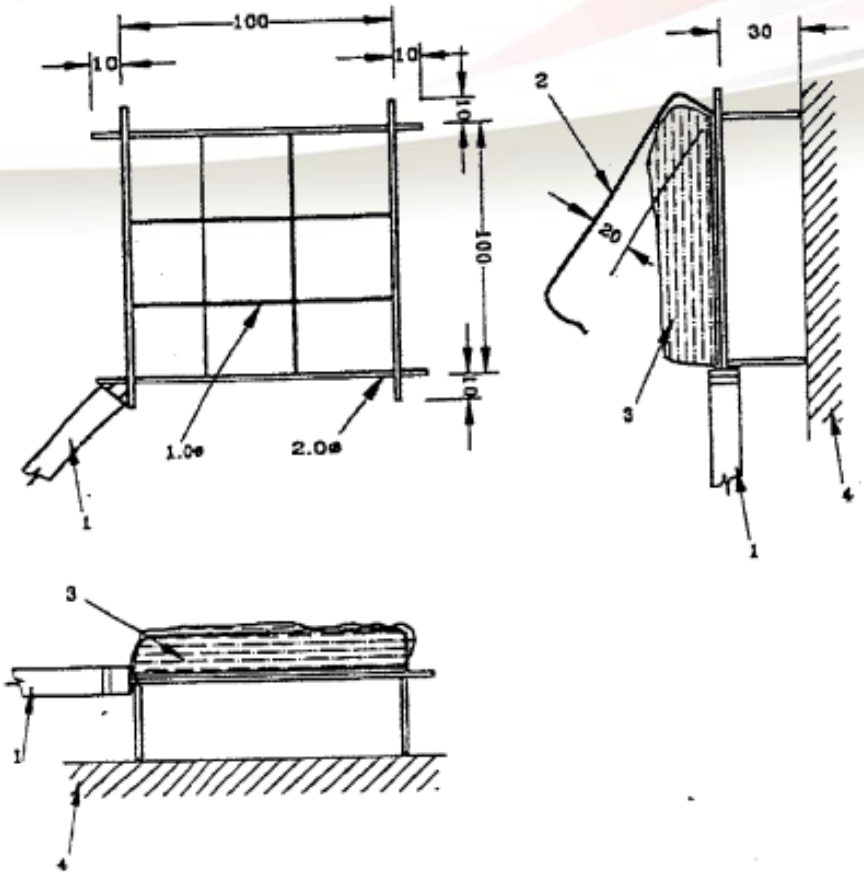
- **Integrity performance**
  - **Evaluated by the test using cotton wool pads, gap gauges and visual monitoring of sustained flaming**

1. **Cotton wool pad test:**
   - **use a cotton wool pad to check suspected hot spot, the possibility of igniting a cotton pad by hot gases even though, there are cracks smaller than that can be assessed by gap gauges**

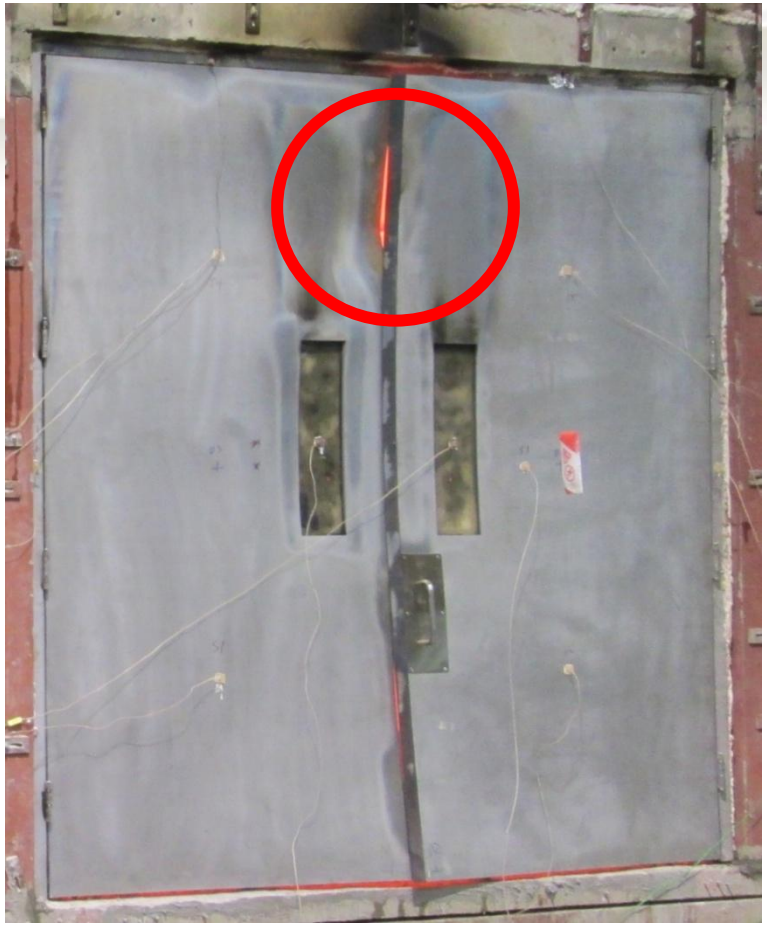
2. **Gap gauges test:**
   - **6 mm gap gauge penetrating through the specimen and move a distance of 150 mm**
   - **25 mm gap gauge penetrating through the specimen**
   - **Check the formation of large cracks**

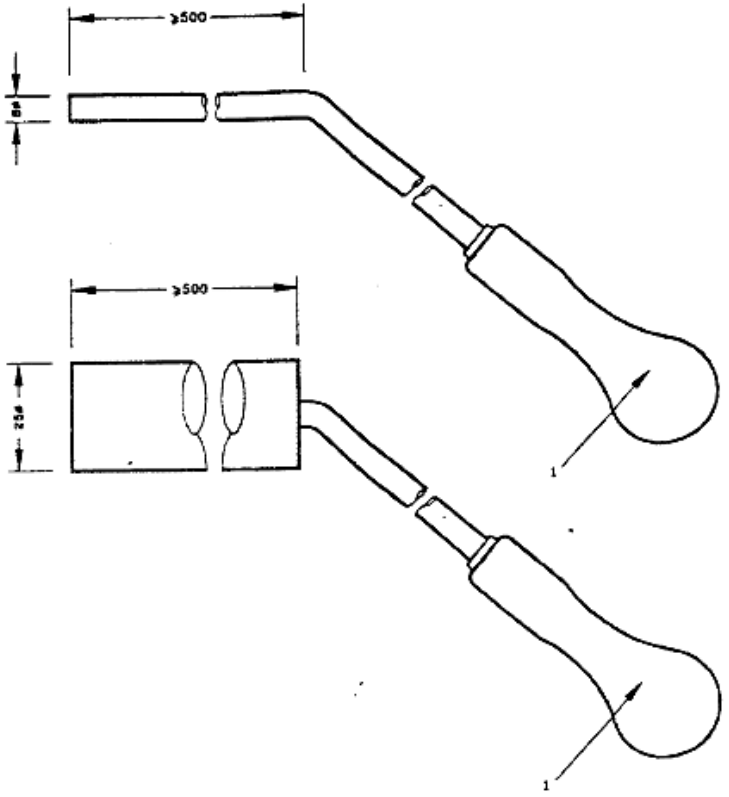
3. **Monitoring of continuous flaming sustained for 10 seconds or more**

Cotton Wool Pad Test



Gap Gauges





Sustained flaming

- **Visual observation, sustain continuously for 10 seconds**

What is Integrity?

- **Prevent the fire or hot gases to penetrating through**
- **No matter how large or small scale of the flame is, as long as it sustained for 10 seconds, the integrity is regarded as fail**
- **Help to prevent fire spread, contain the fire within the compartment**

Insulation performance

- **Insulation performance**
  - **Use of Type K T/Cs attached to the surface of unexposed side**
  - **Use of Type K roving T/C to assess for hot spot area**

- **Performance criteria**
  - **Average temperature rise on unexposed face**
    - **Five T/Cs located at the central region of specimen**
    - **Not exceed 140 ^{o}C rise in temperature**
  - **Maximum temperature rise on unexposed face**
    - **Any point on the unexposed face**
    - **Not exceed 180 ^{o}C rise in temperature**
  - **Failure deemed to be occurred as integrity fails**

Fire Test Standard: BS EN 1364-3

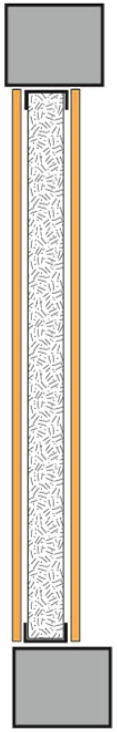
- **BS EN 1364-3**
  - **Full configuration of the curtain walling is tested**
    - **Representative part or parts of the whole curtain walling**
  - **Specimens with the sizes that can be accommodated by the furnace depends on its opening, incorporated the fire rated glazing, horizontal sealing and vertical sealing**
  - **Fixing details as in practice (spacing and the use of materials) or using weaker fixing (for follow up assessment purpose)**
  - **Assess the separation function of the vertical and horizontal sealing to protect the adjacent surfaces not subjected to heat directly**

Fire Test Standard: BS EN 1364-4

- **BS EN 1364-4**
  - **Test on partial configuration, may be the façade which have the spandrel area fire rated but contains non-fire rated glazing outside the spandrel area**
  - **Mainly test on part of the curtain walling system which is fire rated, e.g. spandrel (the upstand and/or downstand and the associated horizontal sealing and the fixing details)**

Fire Test Standards

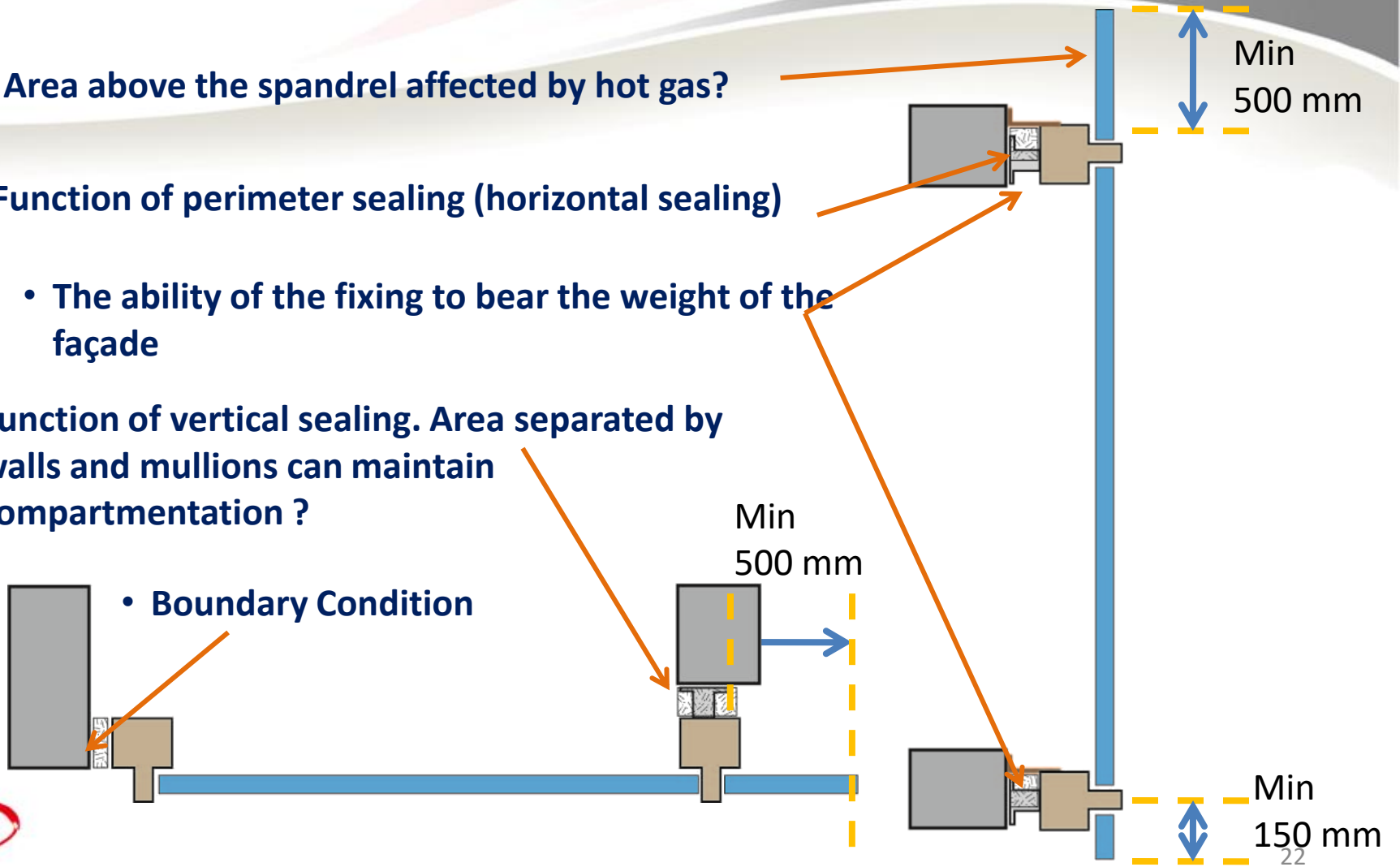
- Test on Partition to BS EN 1364-1
- Symmetrical System
- Fixing at the top and bottom to the slab within the concrete aperture
- Nominal weight bear by the floor
- Assess for
  - Integrity
  - Insulation
  - may be load bearing capacity



- Test on Curtain Walling to BS EN 1364-3
- Asymmetrical System
- Fixing at edge face of the slab
- Fixing to bear the weight of the curtain wall
- Assess for
  - Integrity
  - Insulation
  - Perimeter sealing

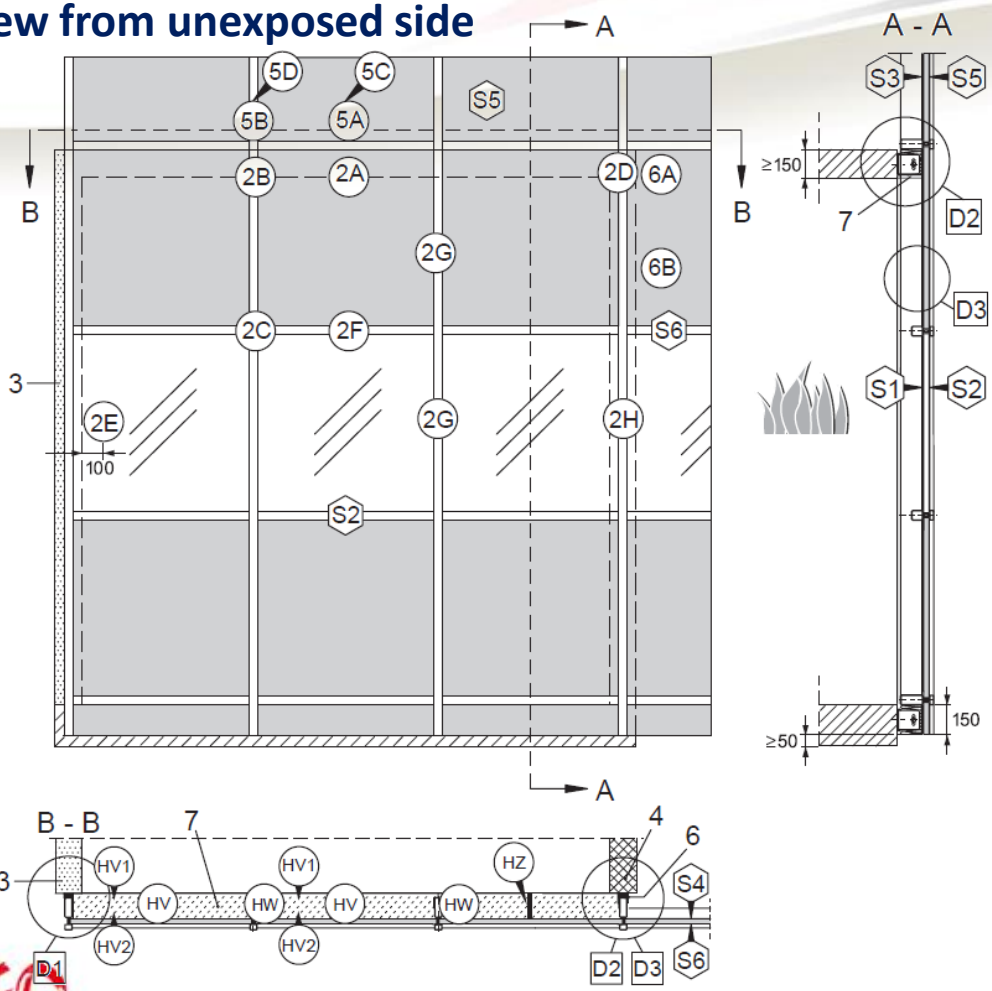
Fire Test Standards

- Area above the spandrel affected by hot gas?
- Function of perimeter sealing (horizontal sealing)
  - The ability of the fixing to bear the weight of the façade
- Function of vertical sealing. Area separated by walls and mullions can maintain compartmentation ?
- Boundary Condition

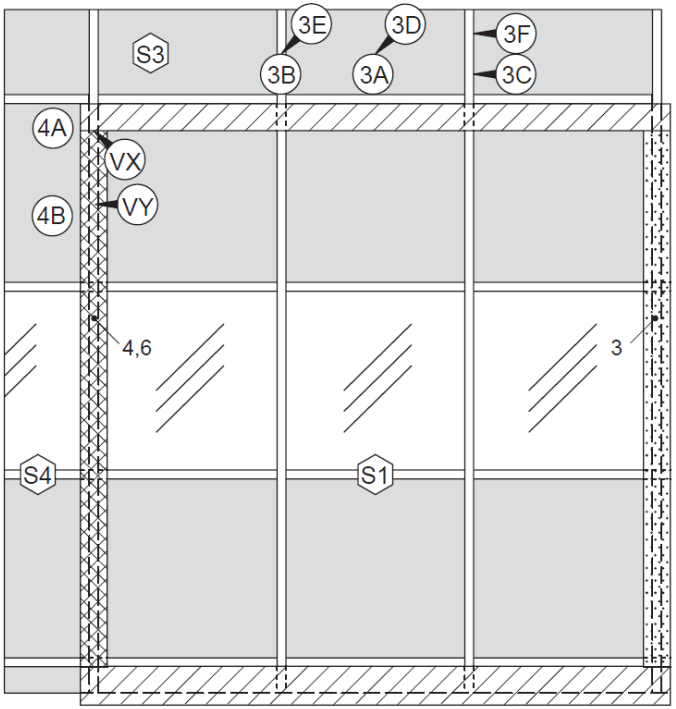


T/Cs locations on each surface and sealings (Internal Exposure)

View from unexposed side

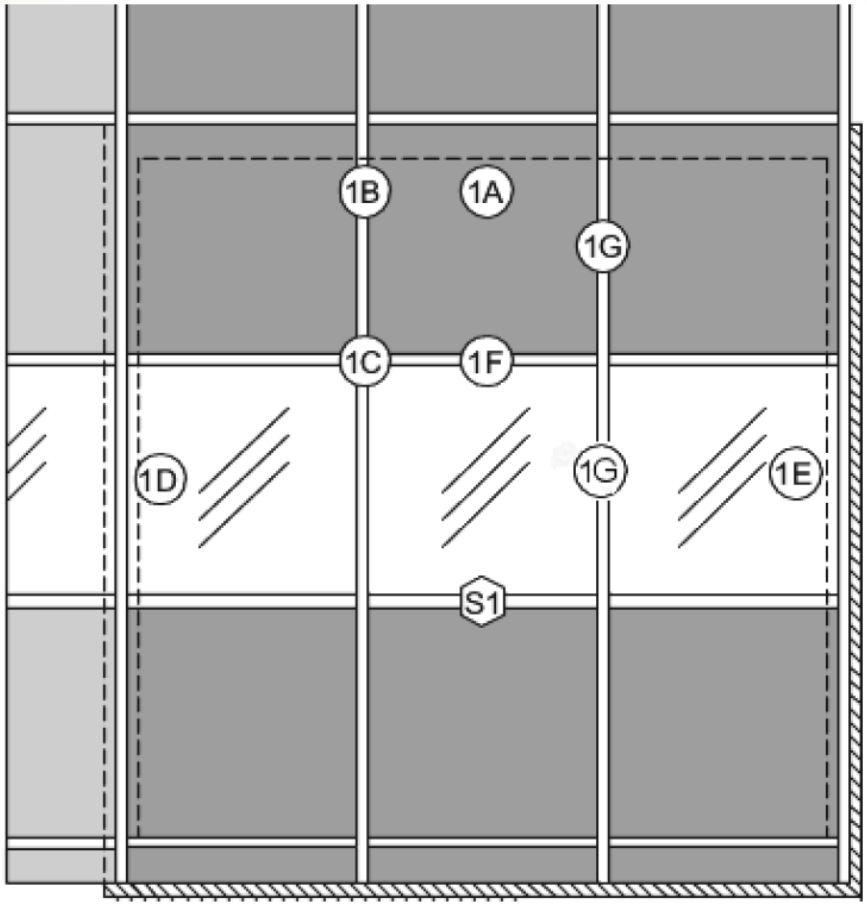


View from exposed side



T/Cs locations on each surface and sealings (External Exposure)

View from unexposed side



Observation during the test

- **Observations below need to be recorded but not the performance criteria in the test:**
  - **Behaviours of fixings**
    - **Failure of fixings**
    - **Sagging of the specimens occurred?**
  - **Falling parts from the external face of the curtain walling**
  - **Deflection of the curtain walling system**

Deflection measurement

- **Measurement of deflection is not compulsory in the test of non-loadbearing element**
- **Measurement will still be taken, as secondary evaluation of the integrity and insulation performance**
- **Large deflection lead to risk in integrity or insulation failure**
- **The deflection data is one of the key consideration for the follow up assessment after the test**

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Fire test: BS EN 1364-3 (External Exposure)

What's the result represent?

For Internal Exposure

Surface or Linear gap seal	Integrity			Insulation (for each discrete area ≥ 0.1 m²)	
	Cotton pad	Gap gauge	Flaming	Mean Temperature	Maximum Temperature
S2#	66	66	59	59*	59*
S3	66	-	66	66	66
S4	66	-	66	66	66
S5#	66	-	66	66	66
S6#	66	-	66	-	66
Horizontal Linear Gap Seal	66	66	66	-	66
Vertical Linear Gap Seal, if required	66	66	66	-	66

Falling Parts, * Insulation deemed not to satisfy as the integrity failed

What's the result represent?

For External Exposure

Surface or Linear gap seal	Integrity			Insulation (for each discrete area ≥ 0.1 m^2	
	Cotton pad	Gap gauge	Flaming	Mean Temperature	Maximum Temperature
S1	67	67	67	67	67
S2#	-	-	-	-	-

Falling Parts

Design the specimen before test

- **Critical to 'design' the test specimen in order to obtain the full and widest range of application, more than one test may be needed to test all the features**
  - **Maximum mullions spacing, maximum gap width for sealing, the potential need for increasing the height span (the sizes of the sections for shorter span in test), etc.**
- **The sizes of the specimen is confined by the opening area of the test furnace (e.g. normally 3m by 3m)**
- **The direct field of application allow maximum increase of 1.5 times of tested span of height (Section 13 of 2014 version referred) provided that**
  - **With 10% performance overrun, deflection < 50 mm and adequate expansion coefficient allowed**
  - **> Tested 3m high span, maximum allowed is 4.5 m span in height**
- **For much longer span (>5 m),**
  - **The test using furnace with higher opening height (e.g. 4 m high furnace), and**
  - **Use of computer calculation, using larger sections to compensate for the required increased moment due to increase in span**
  - **Additional measurement of temperature on the mullions or transoms**

Latest version of BS EN 1364-3 and BS EN 1364-4

- **The CoP Fire Safety nominates BS EN 1364-3: 2006 and BS EN 1364-4: 2007**
- **The test standards BS EN 1364-3 and BS EN 1364-4 had been updated in 2014**
- **In the 2014 version:**
  - **Incorporated the test method of curved (faceted) façade**
  - **More detail in the scope of direct field of application**
  - **Slight difference in the location of unexposed face thermocouples for curtain wall containing fire rated glazing**

Section 2

Clause C10.2

A curtain wall or other similar construction, which protects the building against the elements and which extends beyond one storey in height, should be constructed entirely of non-combustible materials (except for window sealants and gaskets). Any void formed between the curtain wall and the perimeter of the building onto which the curtain wall is fixed should be sealed to form an effective smoke and fire barrier to prevent smoke and fire spread between floors. The smoke and fire barrier should have:

(a) an FRR of not less than that of the floors; and

(b) D-stability duration of not less than the FRR of the floors and the maximum leakage is not more than $25m^3/h/m^2$ at 25Pa at ambient temperature when tested in accordance with BS EN 12101-1.

Heat Resistance / Smoke Control Performance as specified in BS EN 12101-1: 2005 + A1:2006

What is BS EN 12101-1: 2005 + A1: 2006

- **Smoke and heat control systems – Specification of smoke barriers**
  - **A specification, not a test standard**
  - **Describe how to test and which test method shall refer to**
  - **Type of smoke barriers**
    - **Static or active**
    - **Static barriers used at the void between façade and floor slab**

What is BS EN 12101-1: 2005 + A1: 2006

- **Annex D, Clause 5.2: Temperature/time Classification**

Table 1 — Standard classification categories

Classification	Temperature (°C)	Time (min)
D 30	600	30
D 60	600	60
D 90	600	90
D 120	600	120
DA	600	Actual time reached above 120

The heat exposure at 600°C, designated D, represents the constant temperature of the smoke barrier test. The designations 30, 60, 90, 120 represent the period of the smoke barrier test. A smoke barrier which meets the requirements of D 60 also meets the requirements of D 30; equally, a D 90, or D120, smoke barrier also meets the requirements of D 60 and D 30, and D90, respectively. A DA smoke barrier meets all D requirements.

- **Test to vertical type of barrier (e.g automatic drop down smoke curtain)**
- **Using the general principle as in BS EN 1363-1, 3m x 3 m specimen**
- **Only integrity is considered**

Table 2 — Classification categories for smoke barriers operating at higher temperatures

Classification	Temperature (°C)	Time (min)
DH 30	Standard heating curve (EN 1363-1)	30
DH 60	As above	60
DH 90	As above	90
DH 120	As above	120
DHA	As above	Actual time reached above 120

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What is BS EN 12101-1: 2005 + A1: 2006

- **Annex C, Clause 4.4: Smoke (fire effluent) Leakage**

4.4.2 Permeability of materials

The smoke barrier shall be manufactured from materials which restrict the passage of smoke (see Annex C and 5.5.5).

Where a specific system leakage rate is required, a complete product shall be tested to EN 1634–3 (see 5.5.5).

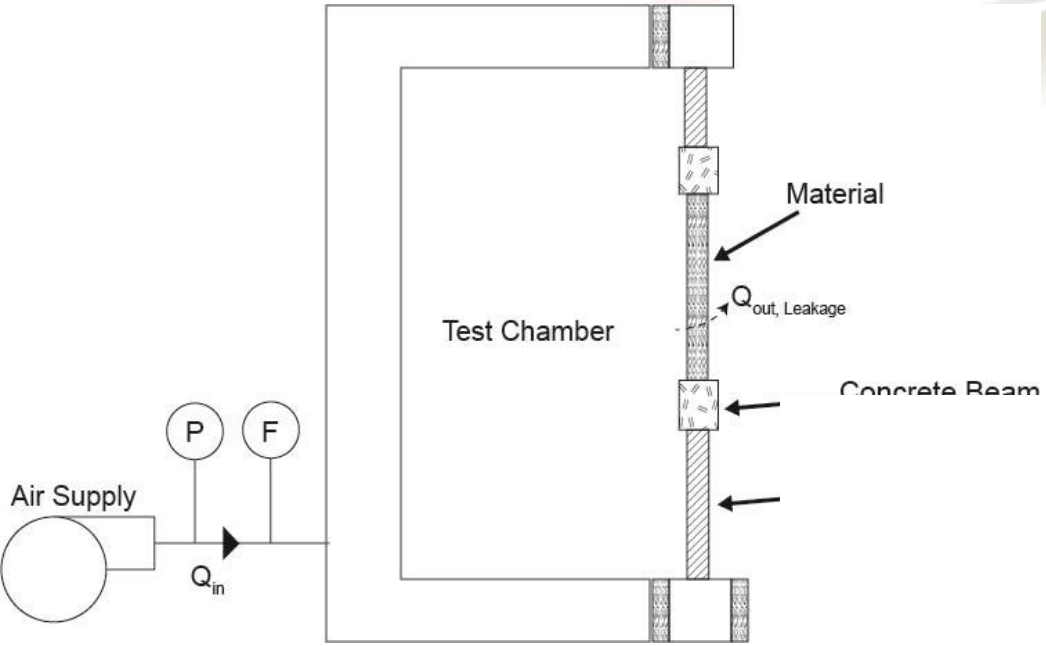
What is BS EN 12101-1: 2005 + A1: 2006

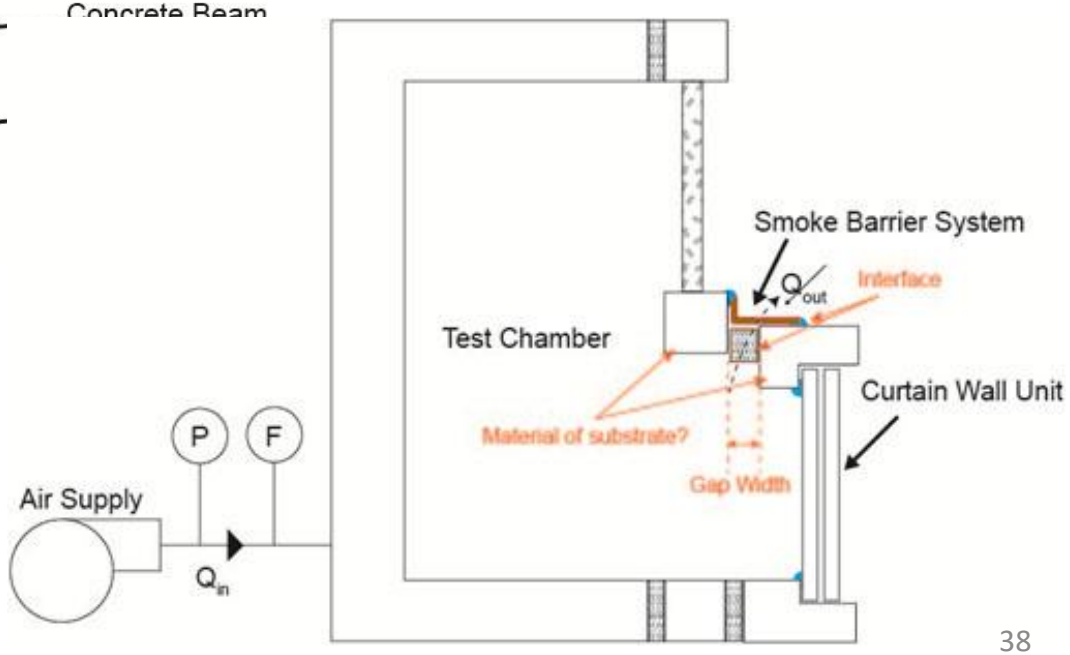
- If checking the permeability of materials, then refer to Annex C
- Test method BS EN 1634-3, using a 1 m^2 sample with edge tightly sealed
- Sample shall have typical seams and joints
- Pressure: 25 Pa, Temperature ambient or 200 ^oC
- Criteria: leakage rate is less than 25 $m^3/h/m^2$

What is BS EN 12101-1: 2005 + A1: 2006

- **Outcome:**
  - **The permeability of the material is good for use as smoke barrier**
- **Limitation:**
  - **May be irrelevant to the smoke leakage rate in the actual system**
  - **Involve fixing details, interface between the substrate (aluminium mullion and concrete slab)**

What is BS EN 12101-1: 2005 + A1: 2006

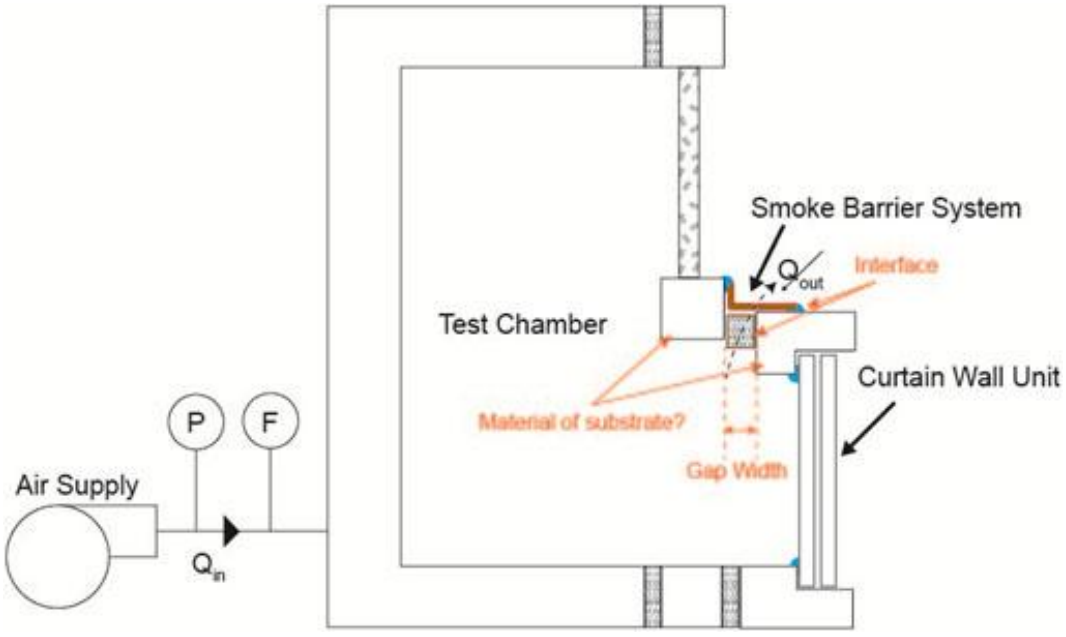




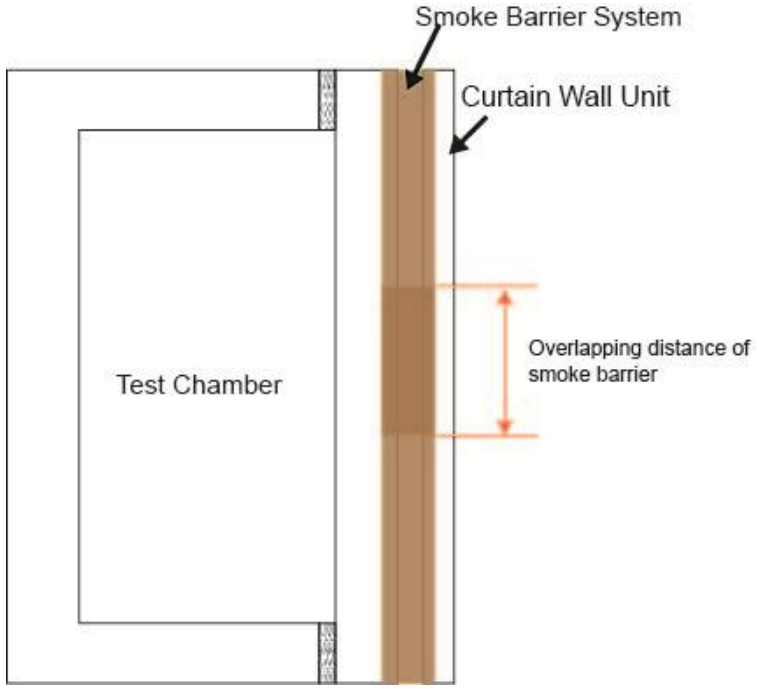
What is BS EN 12101-1: 2005 + A1: 2006

- If go for checking the leakage rate of a smoke barrier system
- Test method BS EN 1634-3, using representative portion with maximum 3m wide
- Sample shall have typical seams and joints as in practice
- Pressure: 25 Pa, Temperature: ambient or 200 ^{o}C
- Criteria: leakage rate is less than 25 $m^3/h/m^2$

What is BS EN 12101-1: 2005 + A1: 2006

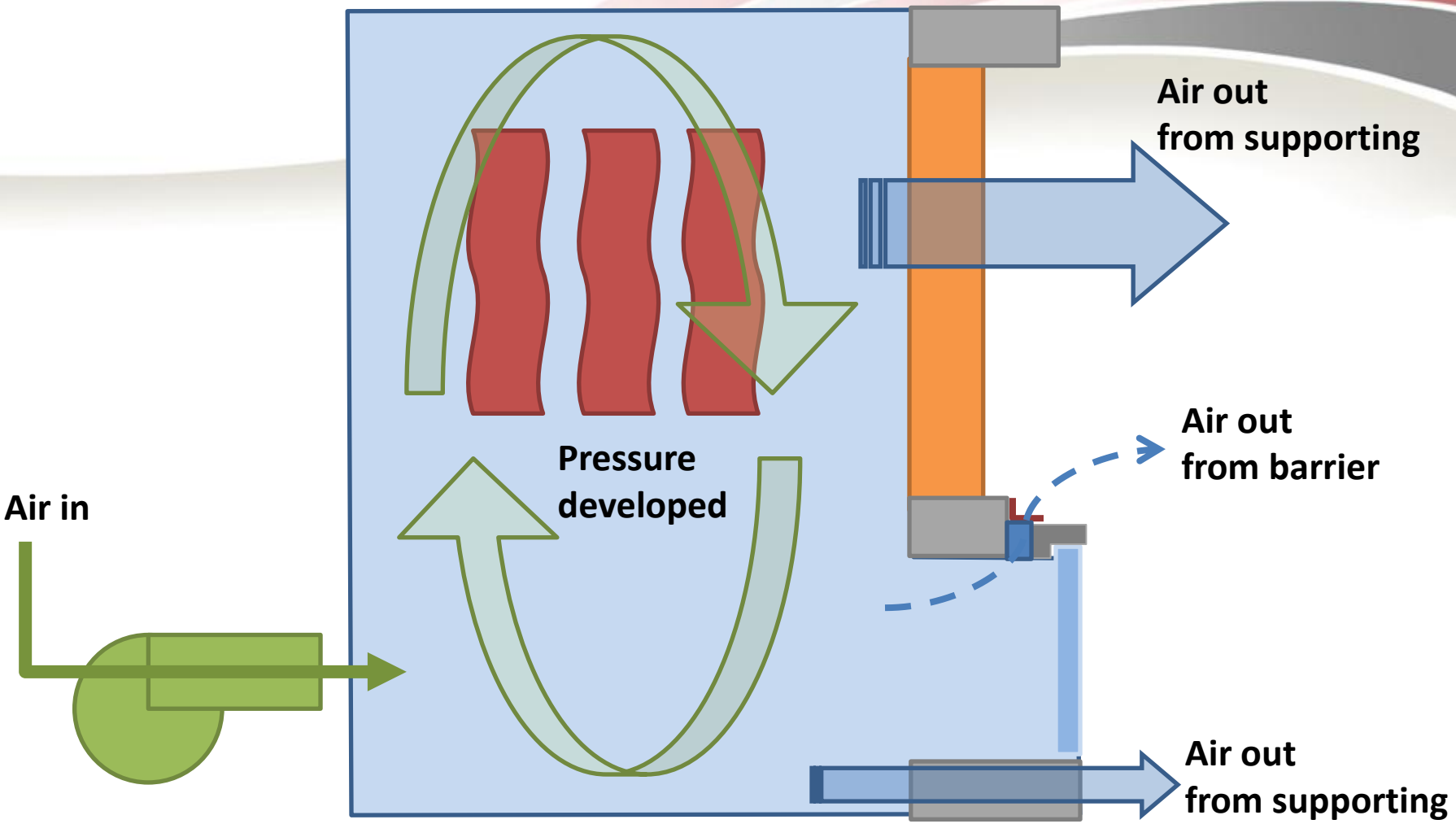


Vertical Section



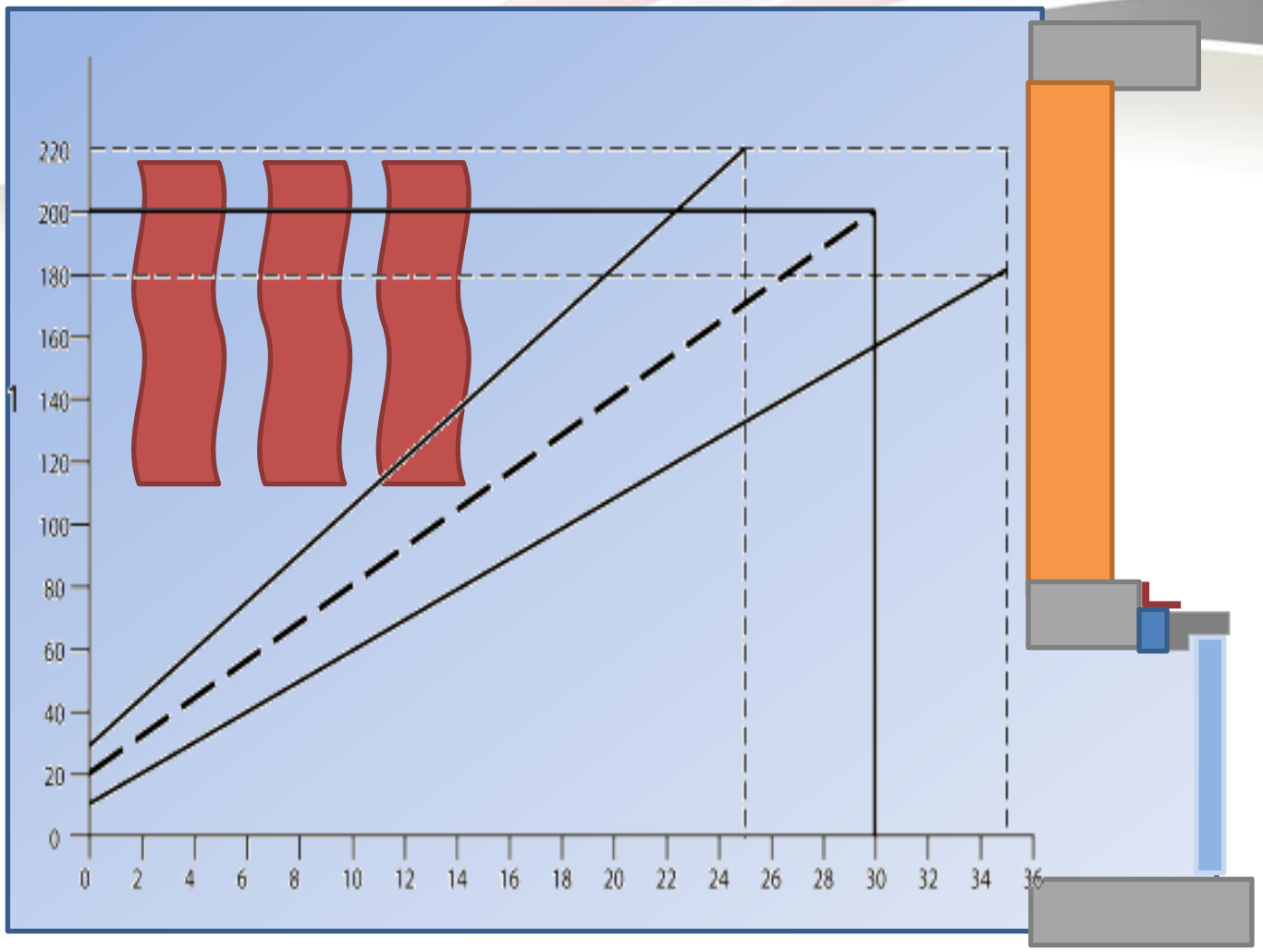
Horizontal Section

BS EN 1634-3 test

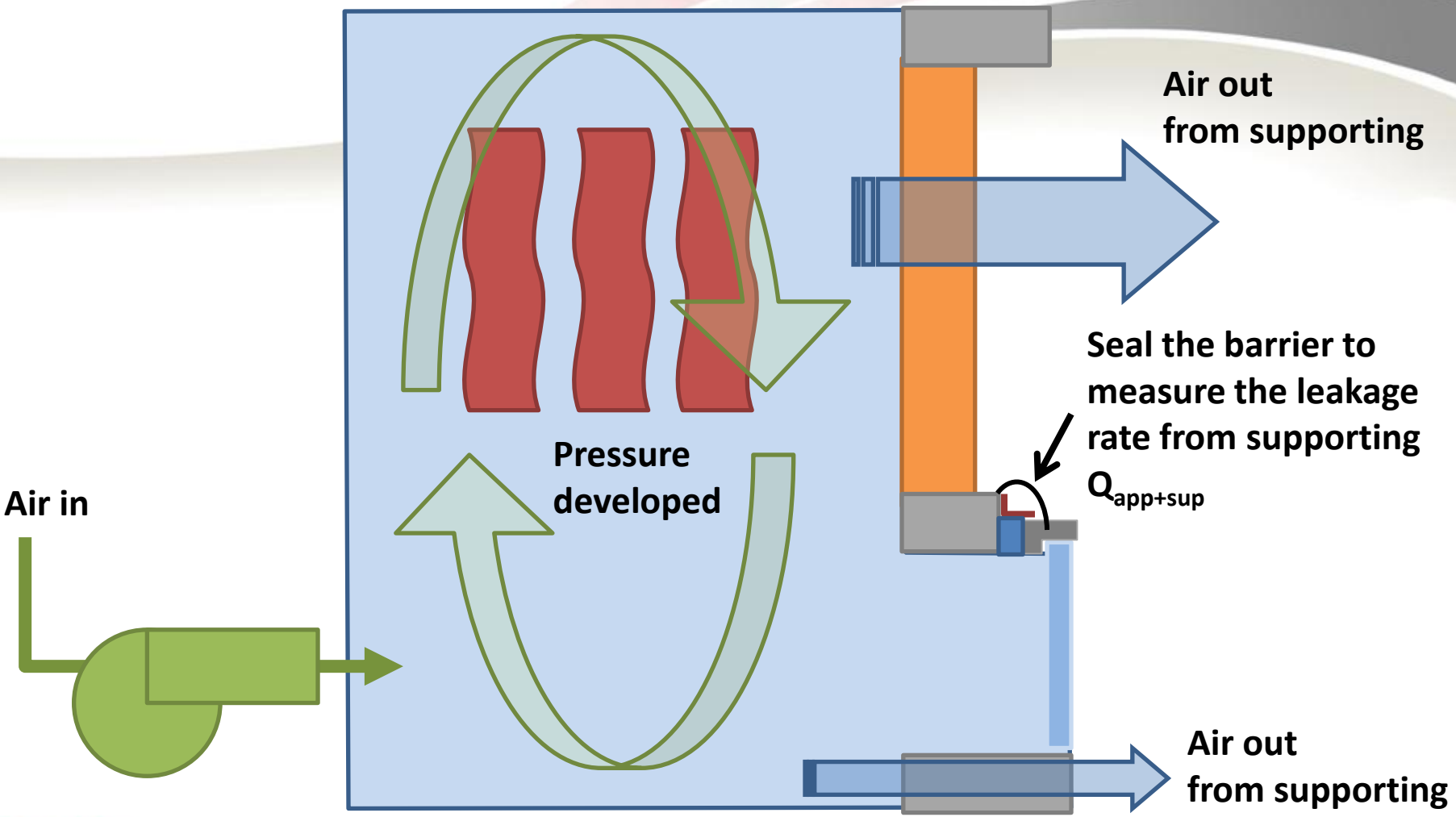


Air in = leakage out at constant pressure

BS EN 1634-3 test condition

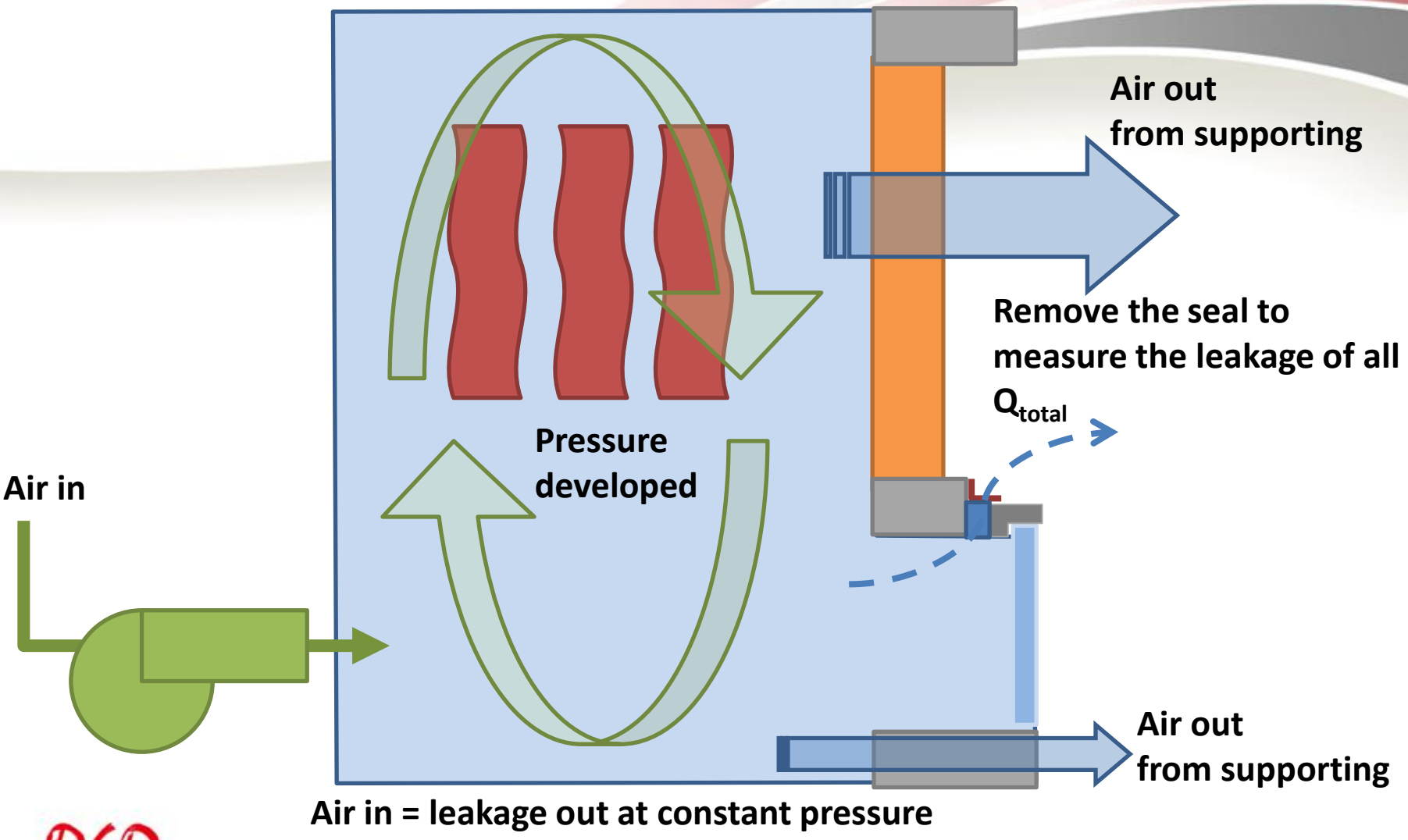


BS EN 1634-3 test



Air in = leakage out at constant pressure

BS EN 1634-3 test



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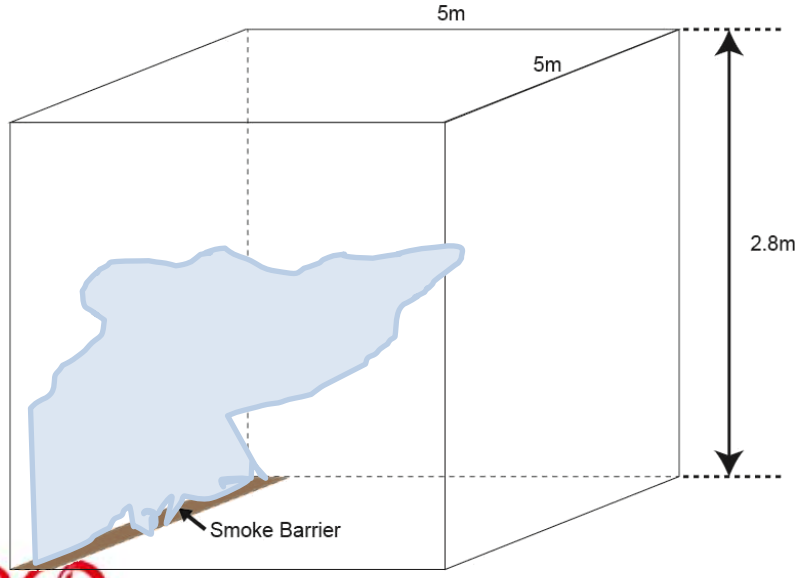
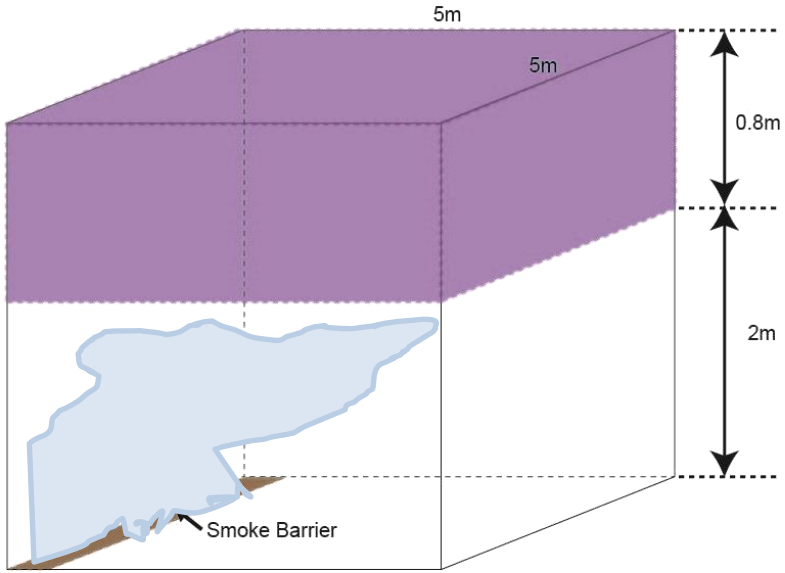
What is BS EN 1634-3

- The leakage rate of door will be
  $Q_{total} - Q_{app+sup}$
- The measurement shall be done for each temperature condition at each pressure point
- Measurement of Q_{total} start after 30 minutes of heating period, and shall be done within 10 minutes
- The pressure shall be constant for 2 minutes and take the measurement

Interpretation of the results

- **Allowable leakage rate of 25 $m^3/h/m^2$:**
  - **Assuming smoke barrier with sizes of 150 mm wide by 5,000 mm long, the leakage rate is assumed to be (25 x 0.15 x 5 =) 18.75 m^3/h**
  - **For a room which is 5 m (w) x 5 m (w) x 0.8 m (h), it will take approximately (20/18.75=) 1.07 hours to fill the upper part of the room and the smoke layer drops to 2 m clear height**





Fire Test?
Smoke Test?

- **Fire Resistance Test and Smoke Control Test are two different tests**
- **The test are conducted separately with the use of different equipments**
- **Tests are conducted under different test conditions**
  - **Under fire test, the door subjected to over 1,000 ^{o}C and 20 Pa at the head of the specimen**
  - **Under smoke test, the barrier subjected to ambient temperature or 200 ^{o}C and up to 50 Pa**
- **The barrier shall subject to the fire resistant test and smoke control test, separately, to prove that its design can satisfy the FRR and Smoke control performance**
- **The performance expression are different, 60 minutes FRR but no 60 minutes smoke control performance**

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Test for a system

- **Both Fire Resistance Test and Smoke Control Test are test on a system but not a material**
- **The System include the installation, the assembly of different material**
- **The failure may due to a number of reason, even for the specimen tested, the result of fire test may be different every time.**

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Fire Test?
Smoke Test?

- **Different way for expression of results:**

Fire Resistance Performance					
Surface or Linear gap seal	Integrity			Insulation (for each discrete area ≥ 0.1 m^2	
	Cotton pad	Gap gauge	Flaming	Mean Temperature	Maximum temperature
S2#	66	66	59	59*	59*
S3	66	-	66	66	66
S4	66	-	66	66	66
S5#	66	-	66	66	66
S6#	66	-	66	-	66
Horizontal Linear Gap Seal	66	66	66	-	66
Vertical Linear Gap Seal, if required	66	66	66	-	66
Smoke Control Performance					
Ambient	25 $m^3/hr/m^2$				
Meidum	25 $m^3/hr/m^2$				

Section 3

Common issue on Tests for Curtain Walling Systems

Code of Practice for Fire Safety in Buildings 2011

- **Extract from CoP Fire Safety 2011**

Clause C10.2

A curtain wall or other similar construction, which protects the building against the elements and which extends beyond one storey in height, should be constructed entirely of non-combustible materials (except for window sealants and gaskets). Any void formed between the curtain wall and the perimeter of the building onto which the curtain wall is fixed should be sealed to form an effective smoke and fire barrier to prevent smoke and fire spread between floors. The smoke and fire barrier should have:

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(b) D-stability duration of not less than the FRR of the floors and the maximum leakage is not more than $25m^3/h/m^2$ at 25Pa at ambient temperature when tested in accordance with BS EN 12101-1.

Fire Resistance Rating?

- **Fire Resistance Period in old CoP**
- **Fire Resistance Rating in CoP 2011**
- **Definition in CoP 2011**

"Fire resistance rating (FRR)" means the period of time that a building element is capable of resisting the action of fire when tested in accordance with ISO 834, BS 476: Parts 20 to 24 or equivalent. Fire resistance ratings are designated by three terms, to represent the make up of the element of construction, i.e. X/Y/Z, where:

- X - Stability fire resistance rating (minutes)
- Y - Integrity fire resistance rating (minutes)
- Z - Insulation fire resistance rating (minutes)

RED

What is the Fire Resistance Test Standard?

Subsection E12 - External Facades

Clause E12.1

External facades should be tested in accordance with the following applicable standards:

(a) BS EN 1364-3:2006, *Fire resistance tests for non-loadbearing elements. Curtain walling. Full configuration (complete assembly)*;

(b) BS EN 1364-4:2007, *Fire resistance tests for non-loadbearing elements. Curtain walling. Part configuration.*

Commentary

There are other options for testing of facades, including:

(a) Large scale testing:

(i) NFPA285:2006, *Standard fire test method for evaluation of fire propagation characteristics of exterior non-loadbearing wall assemblies containing combustible components*;

(ii) ULC-S134-92, *Fire test of exterior wall assemblies (Vertical channel test)*.

(b) Small scale testing:

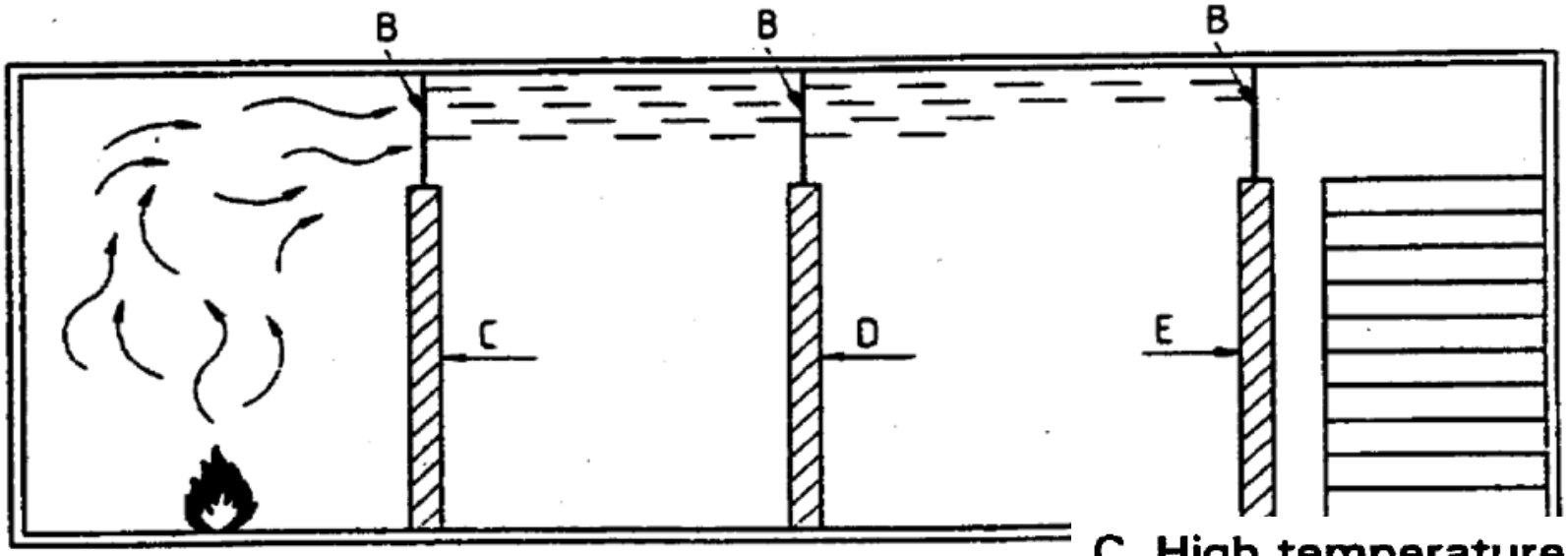
(i) ULC-S134-92, *Fire test of exterior wall assemblies (Vertical channel test)*;

(ii) AS 1530.1:1994, *Methods for fire tests on building materials, components and structures Part 1: combustibility test for materials.*

- **FRR of the barrier at the void?**
- **Which test standard shall refer to?**
- **Is the old BS 476: Part 20: 1987 applicable?**
- **How about if the façade is not fire rated**

The Design to comply with Fire Resistance Performance and Smoke Control Performance

In case of fire, the barrier can't resist fire and at the same time prevent the smoke pass through



C High temperature

D Medium temperature

E Ambient temperature

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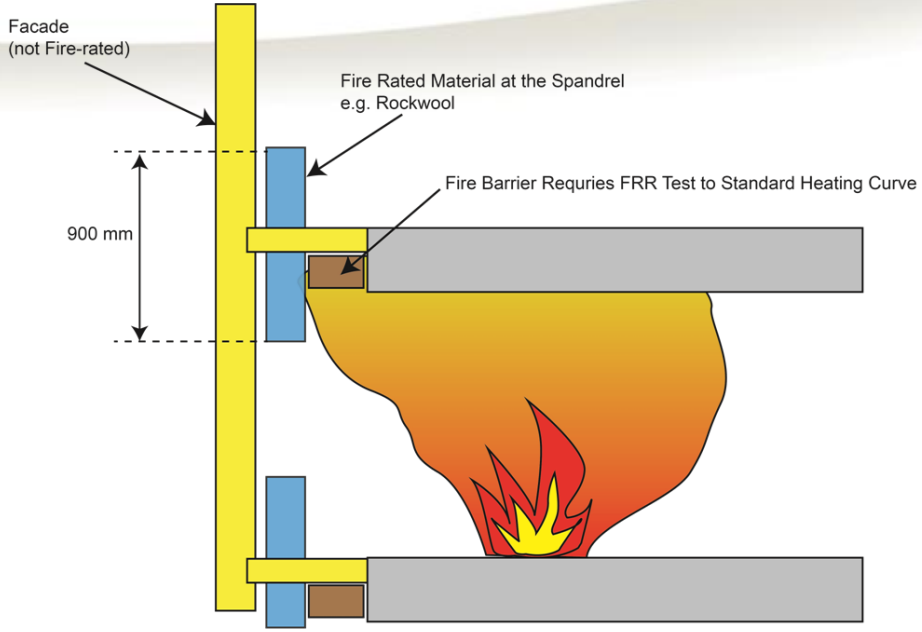
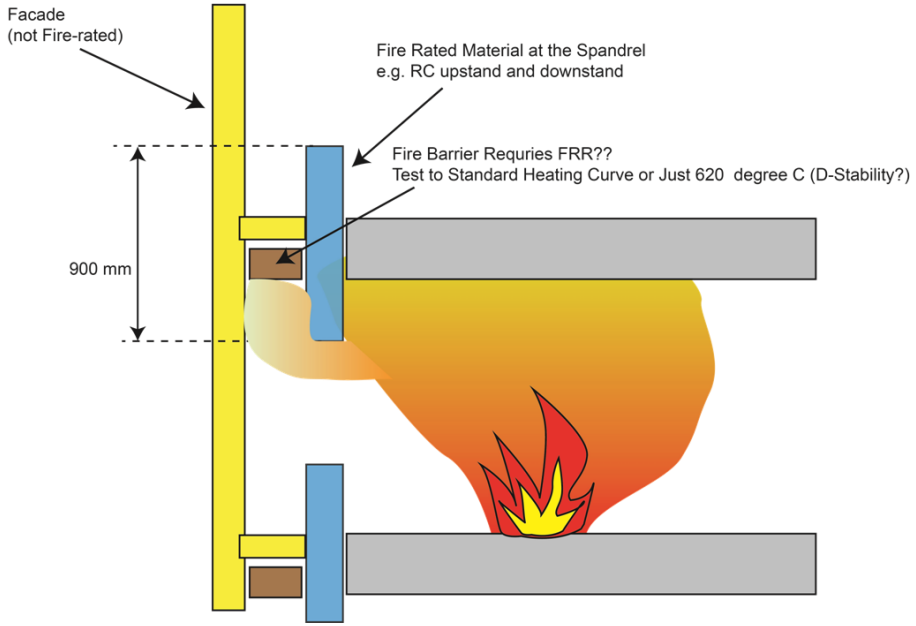
Non-fire rated Façade





Q and A Section

Thank you for your attention

Q and A Section

Extract from BS EN 1364-3: 2014

13.5 Perimeter seals / Vertical linear joint seals

13.5.1 General

Perimeter seals tested according to this standard shall not be used where in practice movement of the perimeter joint is expected.

NOTE For information on test requirements for perimeter seals in case of required movement capability see B.7.8.

B.7.8.3 Movement capability

Rules regarding test requirements in case movement capability for the perimeter seal is required are given in ETAG 026-3.