RED
FIRE ENGINEERS

Combustibility, Flammability and Fire Resistance from Fire Safety Engineering Perspective

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- How does a material spread fire?
- How is a material tested to determine its non-combustibility, flammability and fire resistance, and what is the basis of such testing?
- Is the term ‘limited combustibility’ meaningful from fire safety engineering perspective?
- Does a material with fire resistance rating mean it is non-combustible?
- Is there any correlation between combustibility, flammability and fire resistance?

Introduction

- As a result of recent cladding fires, there is an increased focus on whether materials placed on, or as part of, the external wall are combustible or not.
- There is also a general understanding or perception that some materials are more combustible than the others.

Brain Teaser

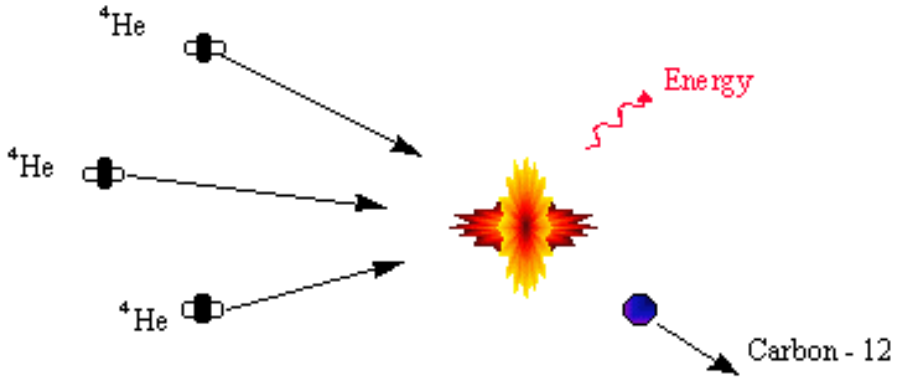
Does helium burn?

Brain Teaser

Helium burning occurs after the star has evolved off the Main Sequence, when it is a red giant.

When the temperature in the core of a star reaches about 100 million degrees, three colliding helium nuclei can fuse to form a carbon nucleus.

This set of reactions is also called the triple alpha process.



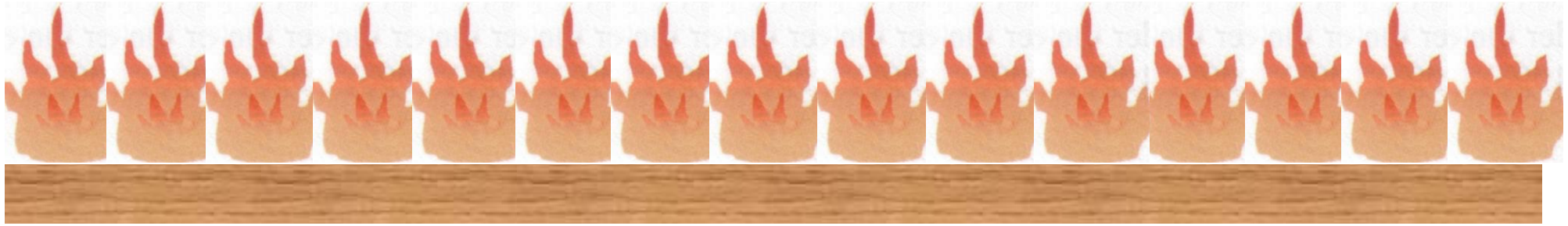
Brain Teaser

Do plasterboards (gypsum boards) burn?

A definition on combustibility (or non-combustibility) is required.
More on this later.

How does fire spread?

Fire spread is a series of continuous piloted ignitions.



Why does a material spread fire?

This is because the material is combustible, and after it is ignited the fire is self-sustaining.

How do We Know a Particular Material is Combustible or Not?

- Prepare specimens of nominally 40 mm × 40 mm, or 45 mm diameter, and 50 mm high. 3 to 5 specimens to be tested, depending on the test standard.
- Place specimens in a small furnace that has reached 750°C in steady state for 10 to 15 minutes.
- Measure the temperatures of the furnace and the specimen, and observe if flaming occurred during the test. Test duration is 20 or 30 minutes, depending on the test standard.

AS 1530.1–1994

ASTM E136-16

BS 476-4:1970

BS 476-11:1982 [ADB]

BS EN ISO 1182:2002

Non-combustible criteria (definition):

The mean duration of sustained flaming is other than zero. [>10 s in BS 476-4]

The mean furnace thermocouple temperature rise > 50 °C. [no rise in ADB]

The mean specimen surface thermocouple temperature rise > 50 °C. [no rise in ADB]

BS EN 13507 (ISO 1182 test) & ASTM E136-16:

$\Delta T \leq 30$ °C; $\Delta m \leq 50\%$; $t_f = 0$ s

Fire Testing on Non-Combustibility (Basis)

- The choice of a furnace temperature of 750 °C for the non-combustibility test started from BS 476 : Part 1: 1953.
- Representative temperature during building fires, although higher temperatures can occur in intense fires.
- For many building materials, complete burning of the combustible fraction will occur as readily at 750 °C as at 900 to 1,000 °C.

Alternative non-combustibility definition

FM Global defines a material is non-combustible when:

- The minimum ash content as per ASTM D482 shall be 90%.
- The maximum gross heat of combustion when tested to ISO 1716 (bomb calorimeter) shall be 2 kJ/g.
- Bench-scale Fire Propagator Apparatus combustion test at 40 % oxygen atmosphere does not reveal any visible flaming for a 15 minutes exposure at 50 kW/m^2 heat flux [1].

[1]. R. L. Alpert and M. M. Khan, "A New Test Method for Rating Materials as Noncombustible," Fire Safety Science-Proceedings of the 7th International Symposium, pp. 791-802, 2003. http://dx.doi.org/10.3801/IAFSS.FSS.7-791.

Limited Combustibility

Materials of limited combustibility are defined in Table A7 of Approved Document B:

a. National class

b. European class

Limited Combustibility

National class

a. Any materials with a density of ≥ 300 kg/m^3, which when tested to BS476: Part 11:1982, does not flame and the temperature rise (furnace thermocouple) is ≤ 20 °C, or

b. Any materials with a non-combustible core at least 8 mm thick having combustible facings not more than 0.5 mm thick (has appropriate flame spread rating where required), or

c. Any materials with a density of < 300 kg/m^3 which does not flame for more than 10 s, and temperature rise (specimen thermocouple) ≤ 35 °C & temperature rise (furnace thermocouple) ≤ 25 °C.

Limited Combustibility

b. European class – Any material/product of Class A2-s3, d2 or better in accordance with BS EN 13501-1:2007.

Note: s3 and d2 means that no performance on the smoke production and flaming droplets is declared.

Limited Combustibility – Fire Safety Engineering Perspective

Combustibility is just one of many characteristics of a material in fire. For fire engineering analysis purposes, the actual gross/net calorific potential (MJ/kg or MJ/m^2) is much more useful than a classification.

Need also to consider:

- Heat release rate
- Flame spread rate
- Smoke growth rate
- Structural strength at elevated temperatures
- Melting point
- Coefficient of expansion

Brain Teaser

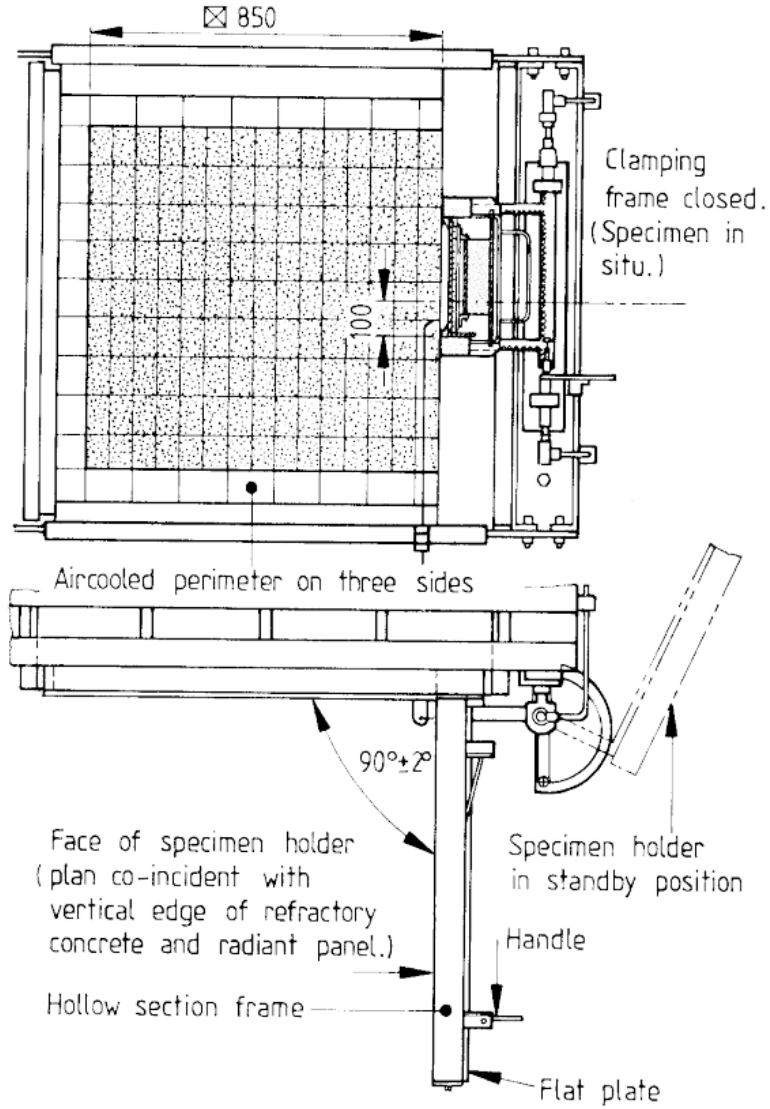
Since flame spread is a series of piloted ignitions at the surface of materials, therefore, a material with a spread of flame index of zero means that the material is non-combustible.

True or False?

Surface Spread of Flame Test

BS 476: Part 7:1997 (1971) 'Surface Spread of Flame Test'

- Original development initiated by some disastrous fires due to rapid flame spread along wall linings.
- The test method was designed to simulate a corridor situation with a fire at one end, the radiant panel being the fire (5 to 32.5 kW/m^2) and the sample being the wall lining.
- Classification of spread of flame (Classes 1 to 4) depending on the distance of spread at 1.5 min and the final spread (test duration 10 min).



Surface Spread of Flame Test

AS/NZS 1530.3:1999
'Simultaneous determination of ignitability, flame propagation, heat release and smoke release'

- Originated as A 30-1935 (being an endorsement of BS 476-1932).
- Heat flux ranges from 2.4 to 30 kW/m^2 when the sample is moved towards the radiant panel at specified intervals.

Surface Spread of Flame Test

- Flame propagation time (s), defined as the time from the moment of ignition for the radiation intensity recorded by the radiometer to increase by 1.4 kW/m^2.

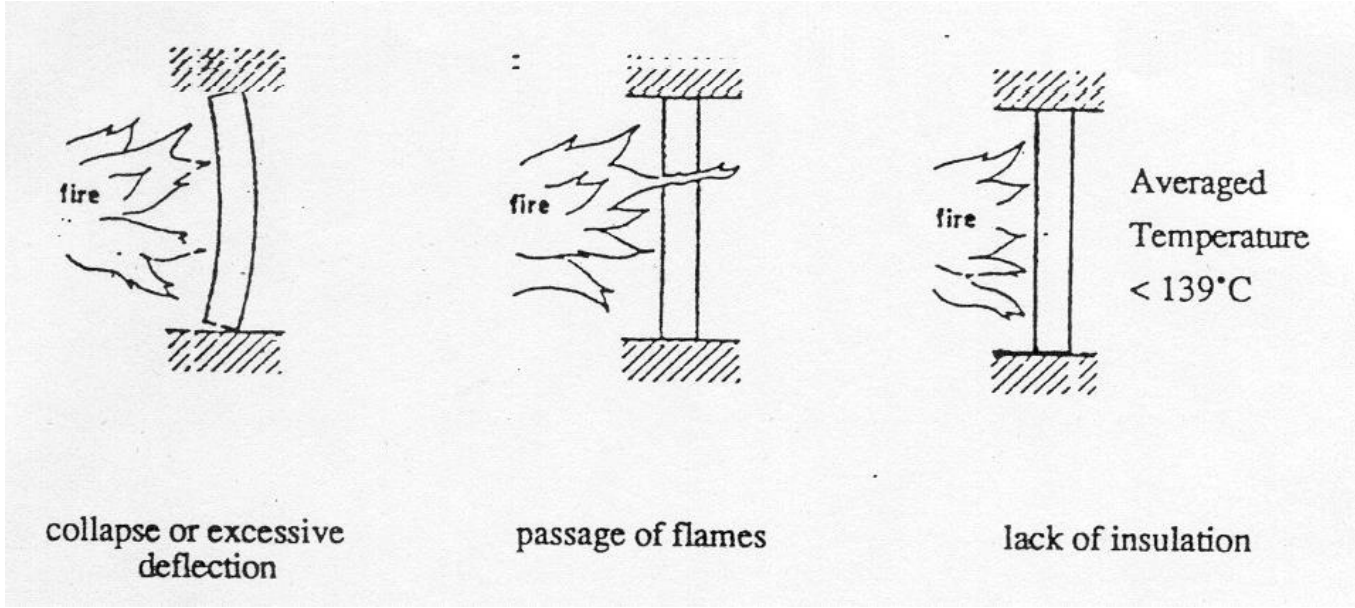
1.33 × mean flame propagation time s		Index
≥ 270		0
≥ 240	< 270	1
≥ 210	< 240	2
≥ 180	< 210	3
≥ 150	< 180	4
≥ 120	< 150	5
≥ 90	< 120	6
≥ 60	< 90	7
≥ 30	< 60	8
≥ 10	< 30	9
	< 10	10

Surface Spread of Flame Test (ACP)

Great Britain	BS 476-6/7	Class 0	BS 476-6/7	Class 0	BS 476-6/7 BS 6853	Class 0 Meets requirements of London Underground Limited Limited Combustible
Australia	ISO 9705 AS/NZ 1530-3	Group 3 (SMOGRA 3.198 m^2/s^2) 0 (Ignitibility) 0 (Flame Spread) 0 (Heat Evolved) 0-1(Smoke Developed)	ISO 9705 AS/NZ 1530-3	Group 1 (SMOGRA 1.385 m^2/s^2) 0 (Ignitibility) 0 (Flame Spread) 0 (Heat Evolved) 0-1(Smoke Developed)	ISO 9705 AS/NZ 1530-3	Group 1 (SMOGRA 0.630 m^2/s^2) 0 (Ignitibility) 0 (Flame Spread) 0 (Heat Evolved) 0-1(Smoke Developed)

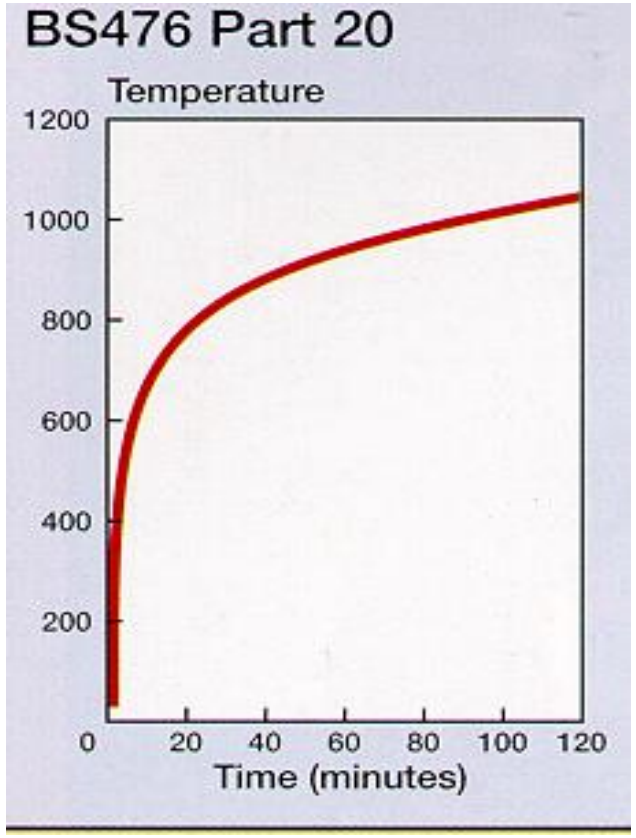
Fire Resistance Testing

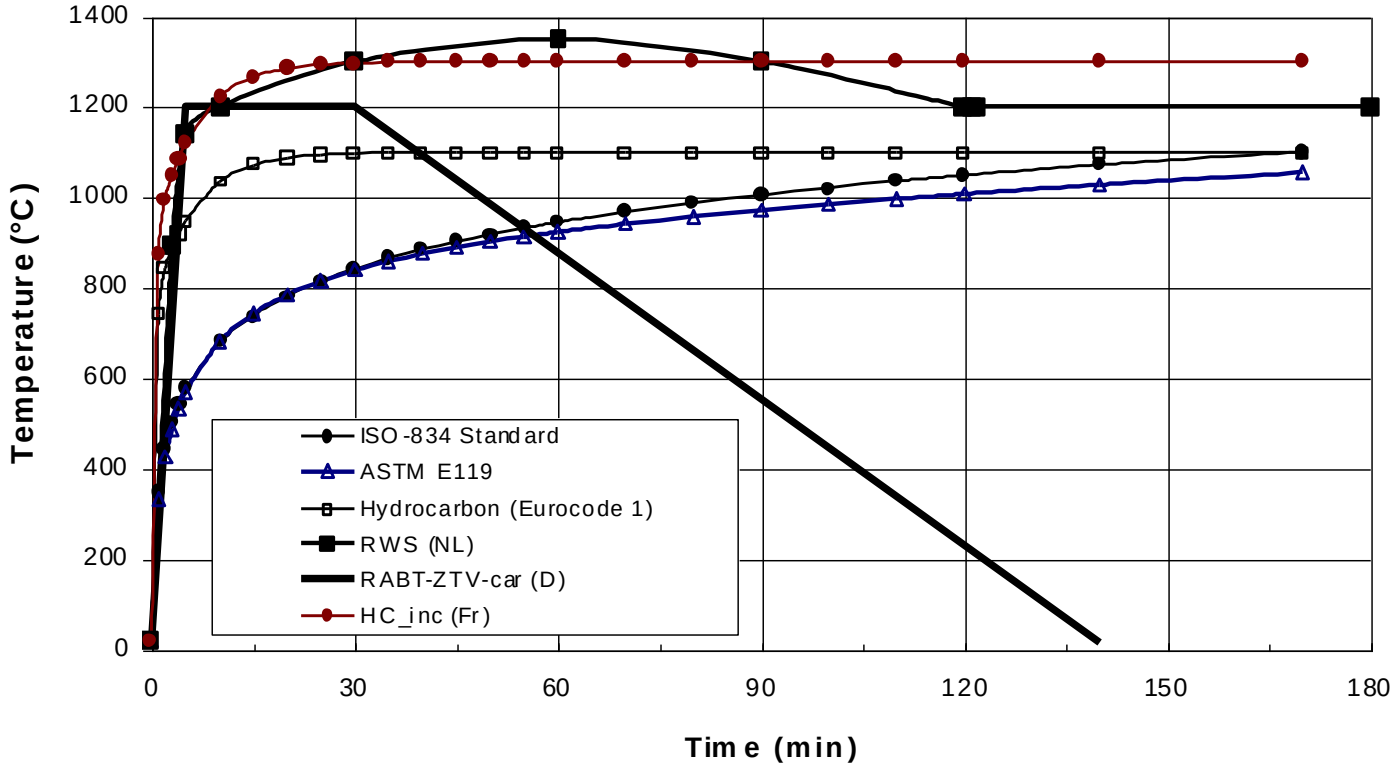
BS 476; BS EN 1363 to 1366 series;
AS 1530.4; ASTM E119 etc.



FRL examples: 120/120/60; –/90/30

Fire Resistance Testing





Fire Resistance Testing

The performance of a building element in the fire resistance test may be quite difference from its performance in natural fires [2].

The time that describes the fire resisting performance of a building element is not a real time; the actual behaviour could be better or worse than the performance tested in a fire resistance furnace. Fire safety also depends on smoke and toxicity.

[2]. Daniel Joyeux, "Experimental investigation of fire door behavior during a natural fire," Fire Safety Journal, Vol. 37 pp. 605-614, 2002.

Fire Resistance Testing

https://www.youtube.com/watch?v=lE8TJTGRxU0&t=37s

Brain Teaser

Does a material/system with fire resistance rating mean it is non-combustible?

There is not any relationship between the fire resistance performance of a material/system with its non-combustibility; for instance, a timber doorset can have a performance of 120/120/30 but is combustible.

Inter-Relationships

- Can the non-combustibility test result for a material be used to predict flammability of such material and vice versa?
- Can the non-combustibility test result or flammability test result for a material be used to predict the fire resistance performance of such material and vice versa?
- No, at least not with the testing protocols we are using to date, and the lack of a mature predictive pyrolysis and combustion model.
- Generally, non-combustibility and flammability performance relevant to occupants in the area of fire origin. Fire resistance performance relevant to occupants on the other side of the area of fire origin.

Conclusions

- Non-combustibility of materials is dependent on the test method and test conditions, as well as the definition.
- No direct engineering relationships between non-combustibility, flammability and fire resistance performance, based on the testing protocols we use to date and the lack of engineering tools in pyrolysis and combustion predictions.
- Limited combustibility is a classification for regulatory purposes, with little engineering data.
- Fire resistant assemblies can contain combustible materials but it is the overall performance that matters.

Thank you

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