Tunnel Fires & Trade-offs

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40 Years of tunnel fires?

1975: Moorgate, London, 44 fatalities | Mexico City Subway, 50 fatalities
1979: Nihonzaka Tunnel, Japan, 7 fatalities, 189 vehicles destroyed
1982: Caldecott Tunnel, USA, 7 fatalities, multiple vehicles inc. tanker
1984: Summit Tunnel, UK, train with 13 tankers of petrol
1987: King's Cross, London, 31 fatalities
1993: Serra a Ripoli Tunnel, Italy, 4 fatalities, 5 HGV & 11 cars destroyed
1995: Baku Subway, Azerbaijan, 260 fatalities!
1996: Channel Tunnel fire, 10 HGV and carrier wagons
1999: Mont Blanc Tunnel, 39 fatalities, 34 vehicles destroyed
2000: Kaprun funicular railway tunnel, Austria, 155 fatalities
2001: St Gotthard Tunnel, Switzerland, 11 fatalities, 23 vehicles
2003: Daegu subway fire, South Korea, nearly 200 fatalities!
2005: Frejus Tunnel, 2 fatalities, 4 HGV destroyed
2007: Burnley Tunnel, Australia, no fatalities, fire contained by deluge
2008: Channel Tunnel fire, 650m of tunnel lining destroyed
2009: Eiksund Tunnel, Norway, 5 fatalities
2013: Brattli Tunnel, Norway, fire burned for 5 days! (Brunost cheese)

20 years ago...

Happy Birthday Channel Tunnel!

What do we know now that we didn't know 40 years ago?

(and what role did Edinburgh people play in this?)

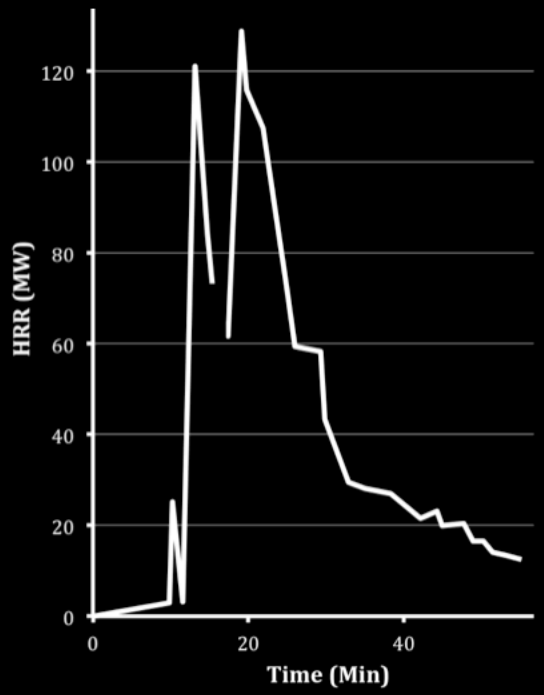
How big is a tunnel fire?

70s answer: HGV = 20 MW

(Heselden, 1976)

90s answer:

(Grant & Drysdale, 1995)



00s answer: could be much bigger…

(Carvel & Beard, 2001)

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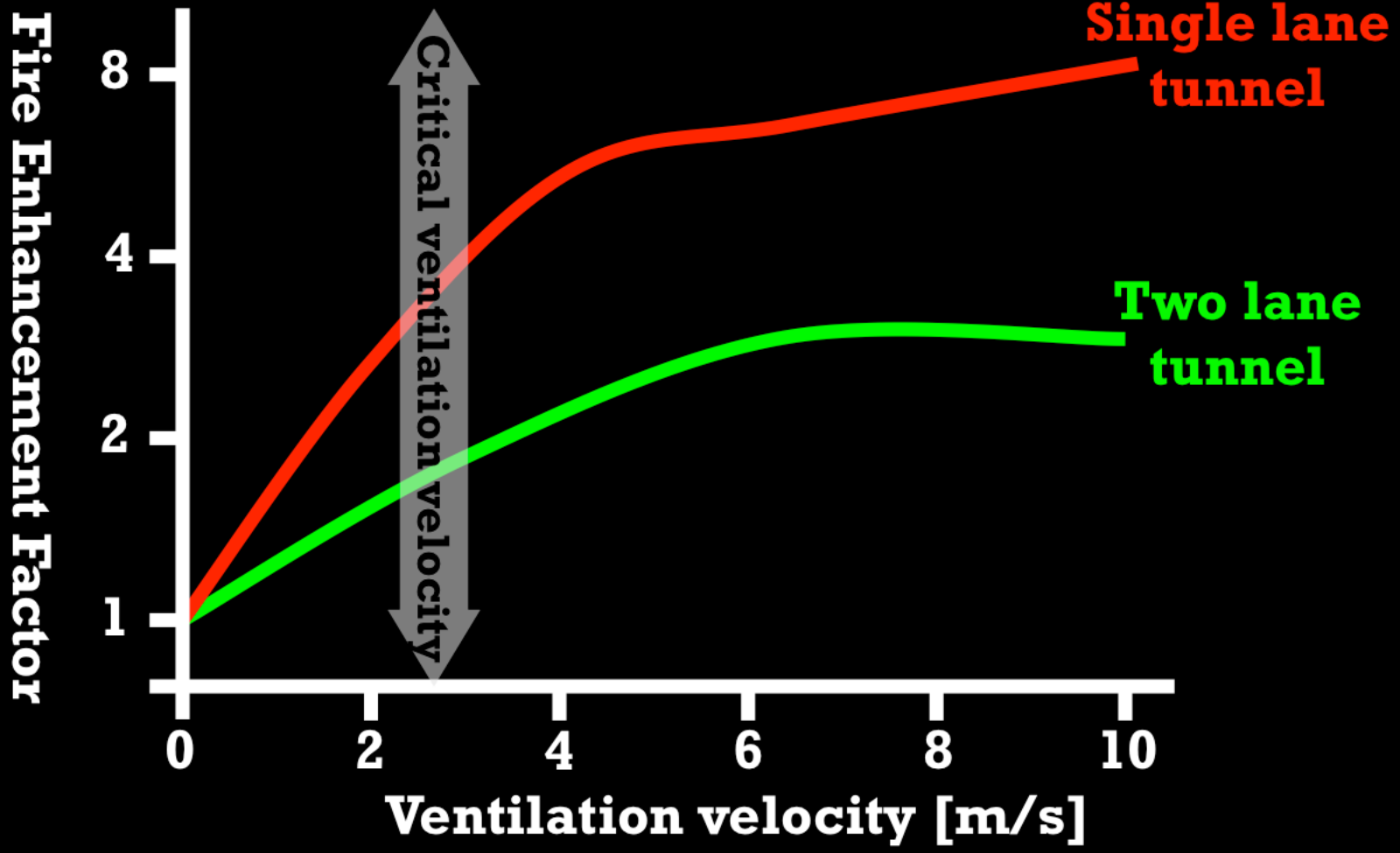


What is Critical Ventilation Velocity?

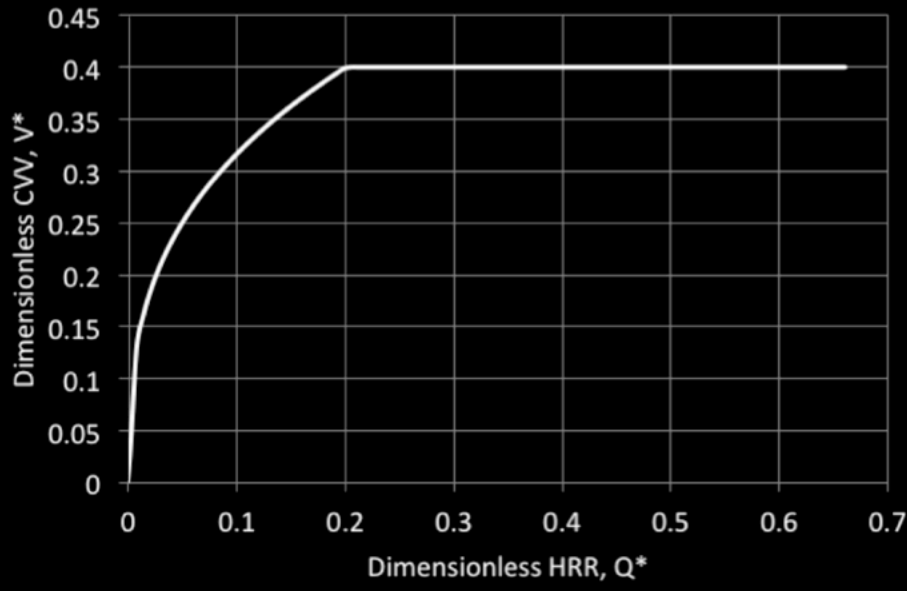
70s answer:

(Thomas, 1970)

$$Q = \frac{V^3 \rho c_p T w_t}{g}$$

90s answer:

(Oka & Atkinson, 1995)



00s answer: characteristics scale with $\overline{H}$

(Wu & Bakar, 2000)

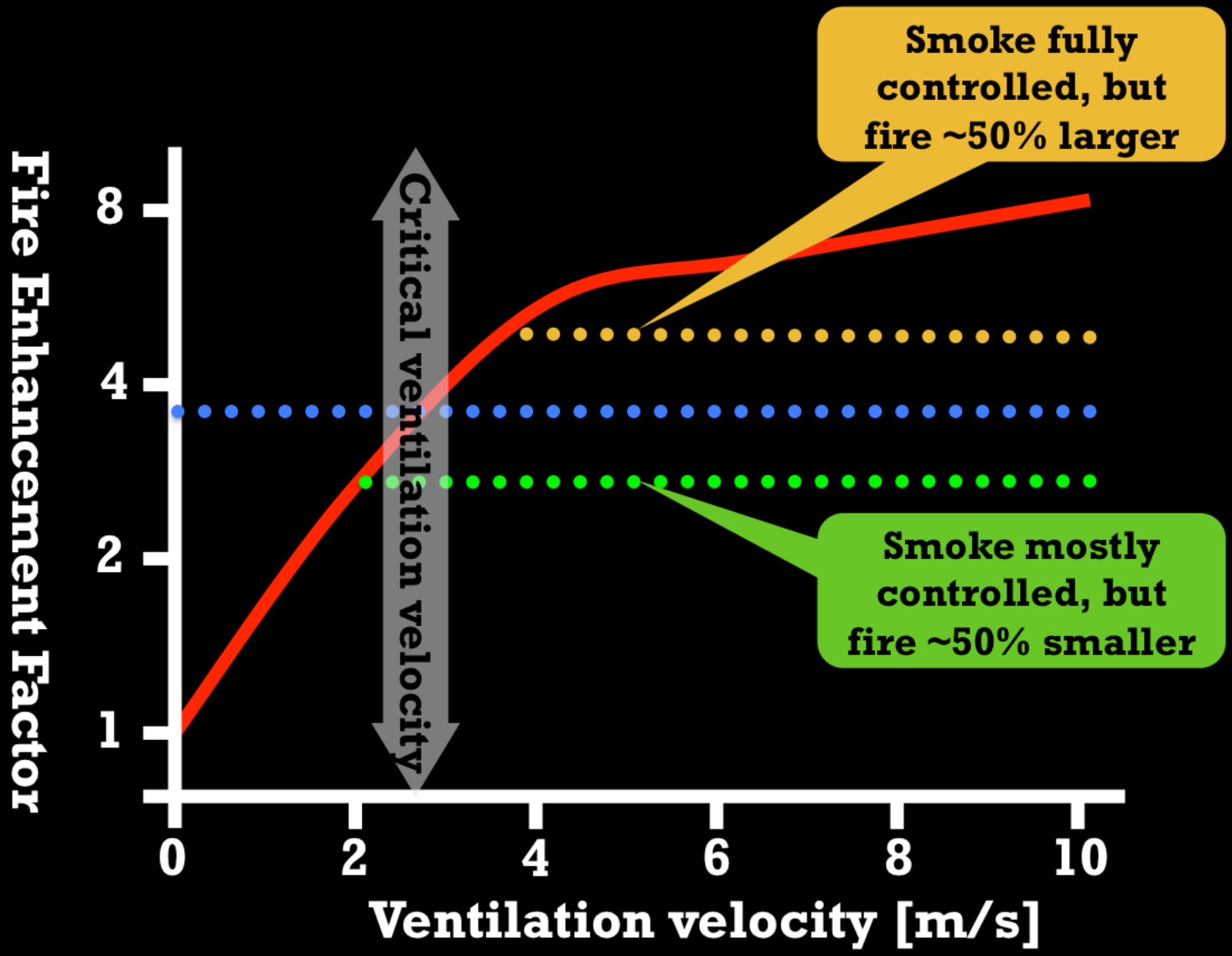
Trade-off #1

Ventilation required for smoke control

vs.

Increased ventilation leads to larger fires

Trade-off #1

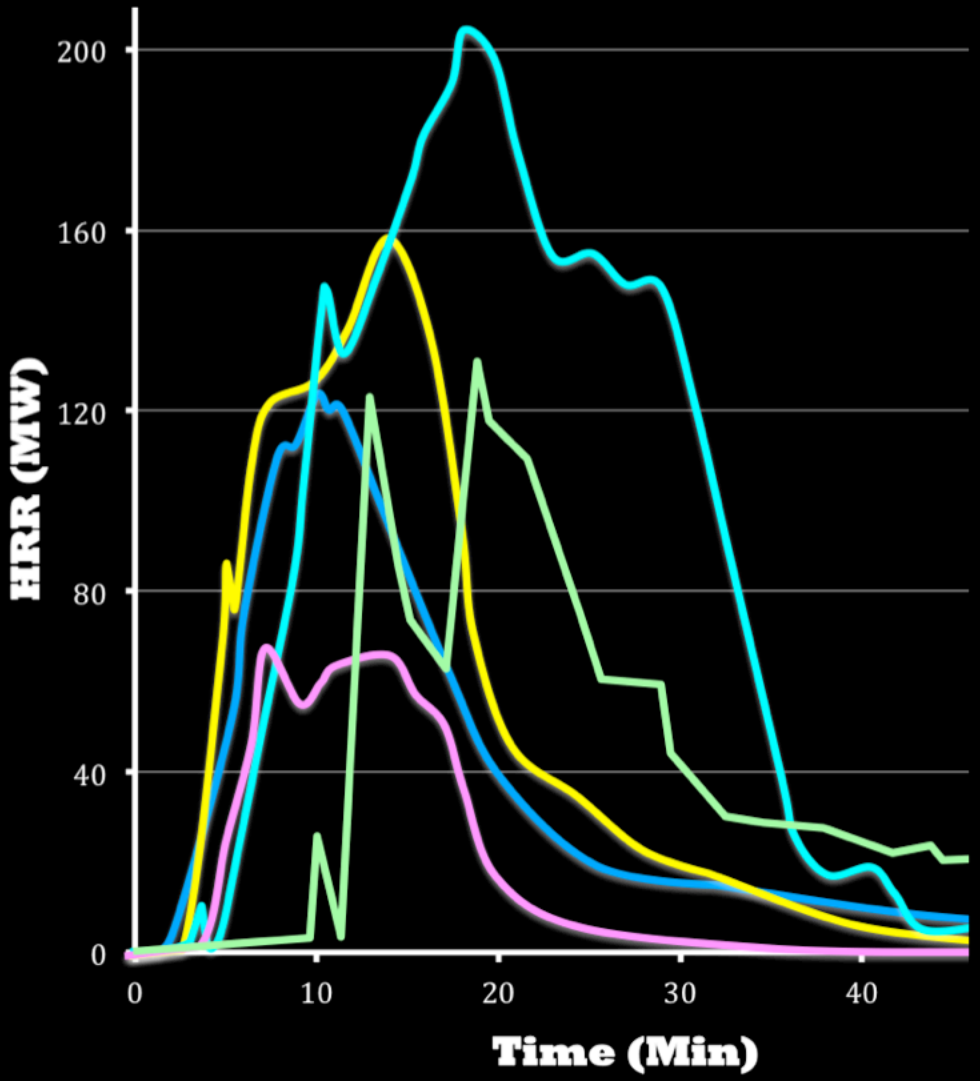

Smoke fully controlled, but fire ~50% larger
Smoke mostly controlled, but fire ~50% smaller
Critical ventilation velocity
Fire Enhancement Factor
1
2
4
8
0
2
4
6
8
10
Ventilation velocity [m/s]

What does a tunnel "design fire" look like?

70s thinking: Pick a design fire (20MW will do) and design ventilation system to deal with the smoke…

10s thinking: The ventilation flow defines the fire behaviour and size. What kind of a fire do you want to have to deal with?

What does a real tunnel fire look like?



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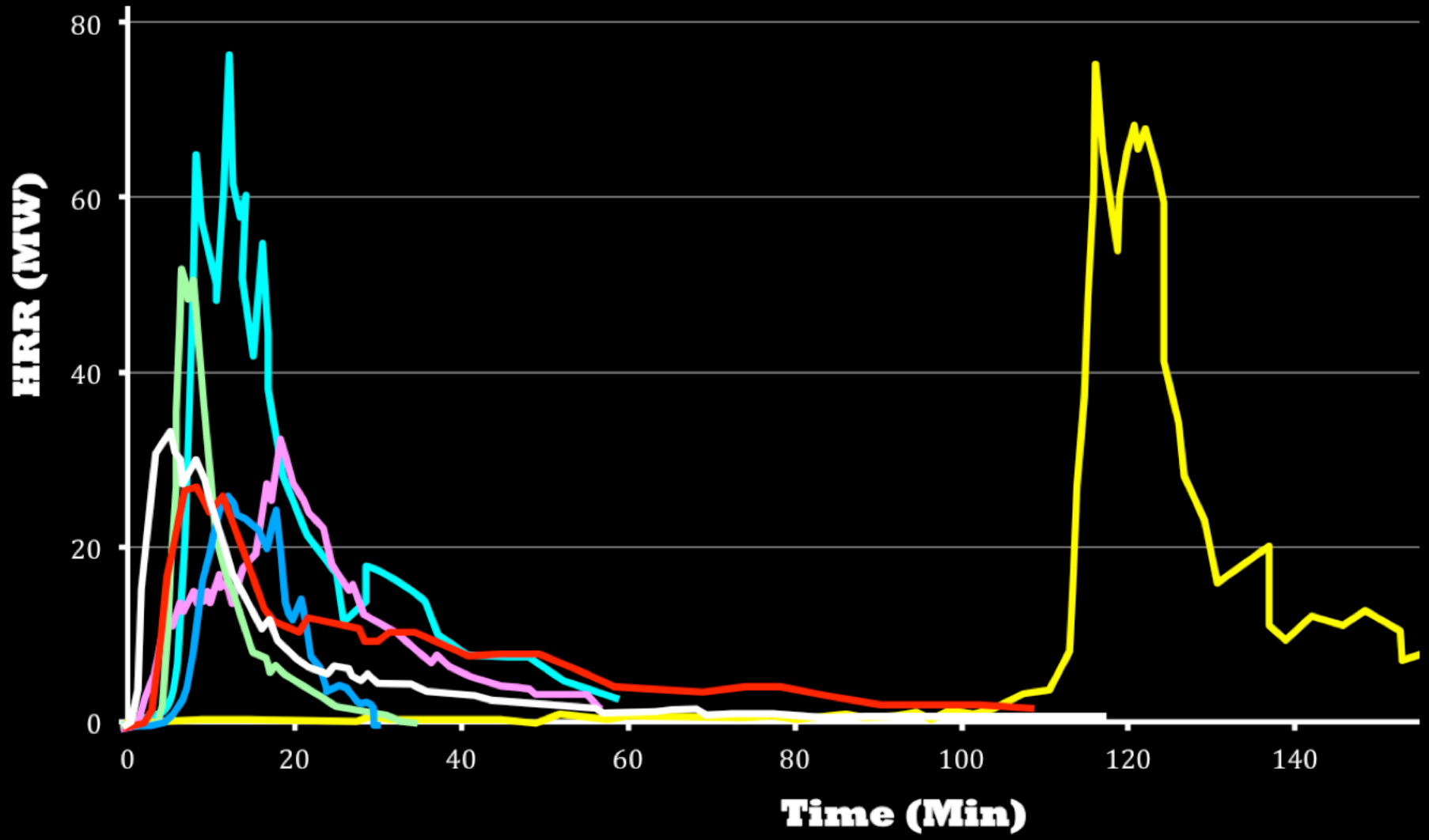

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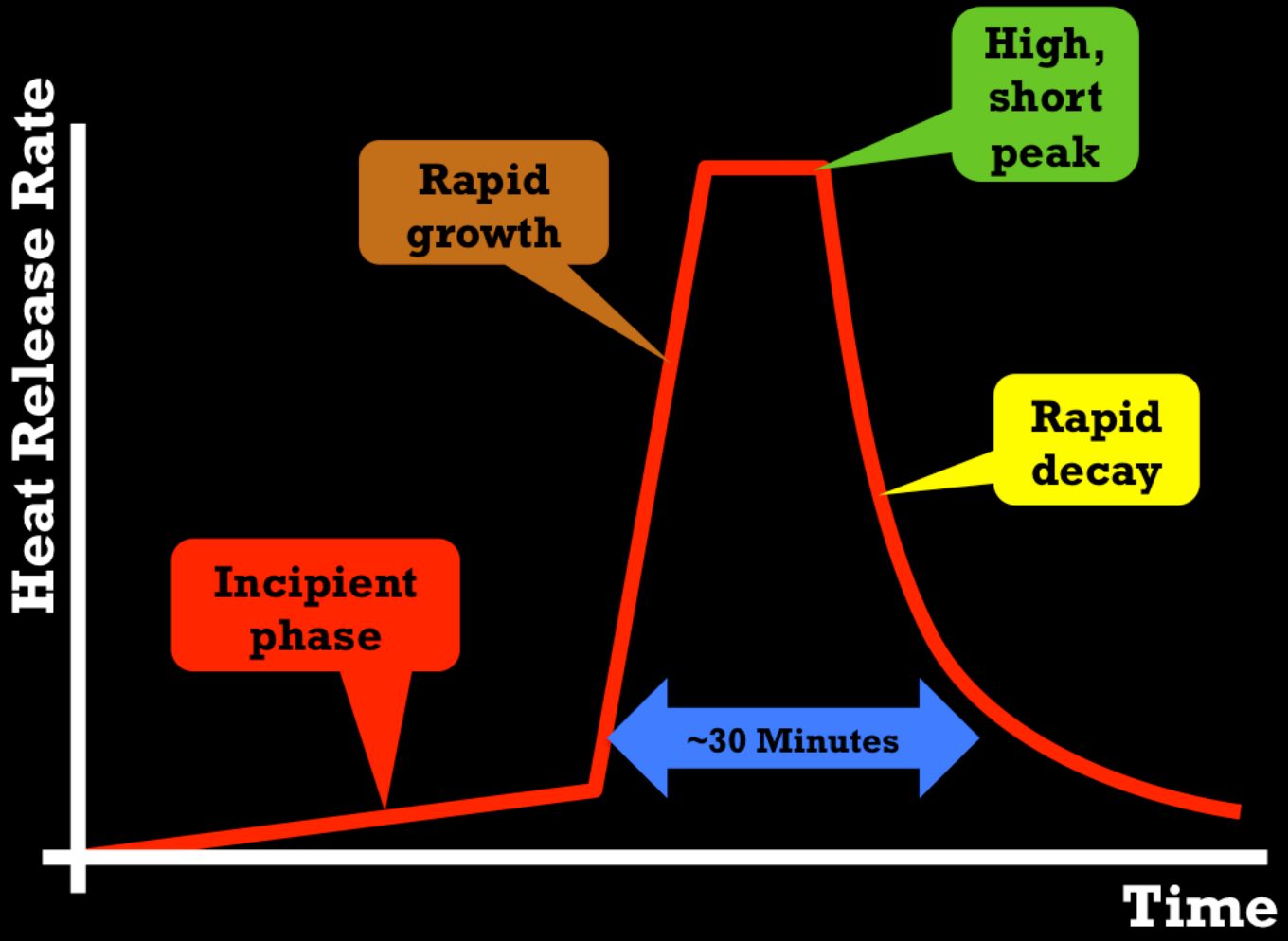
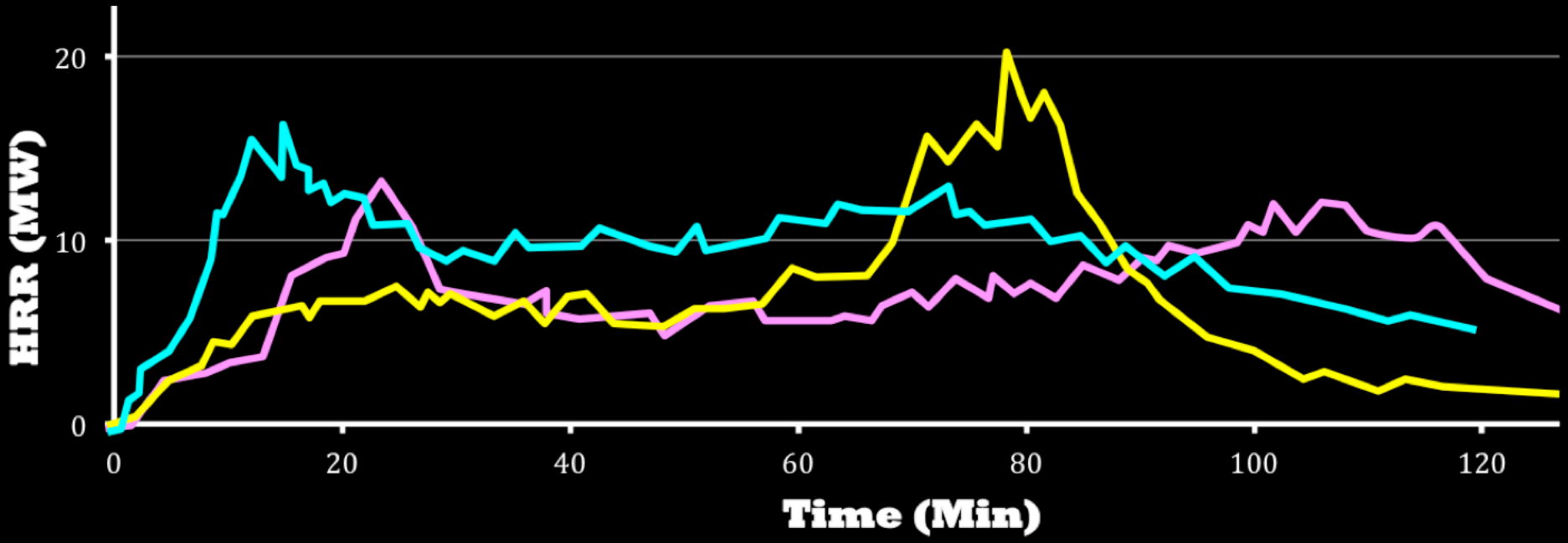


What does a real tunnel fire look like?

But what about these?



Trade-off #2

You want a small fire?

Don't use mechanical ventilation

vs.

You want smoke control?

You'll have to deal with a large fire

(Yes, that's basically the same trade-off as #1…)

Trade-off #2b

Small, long duration fire

vs.

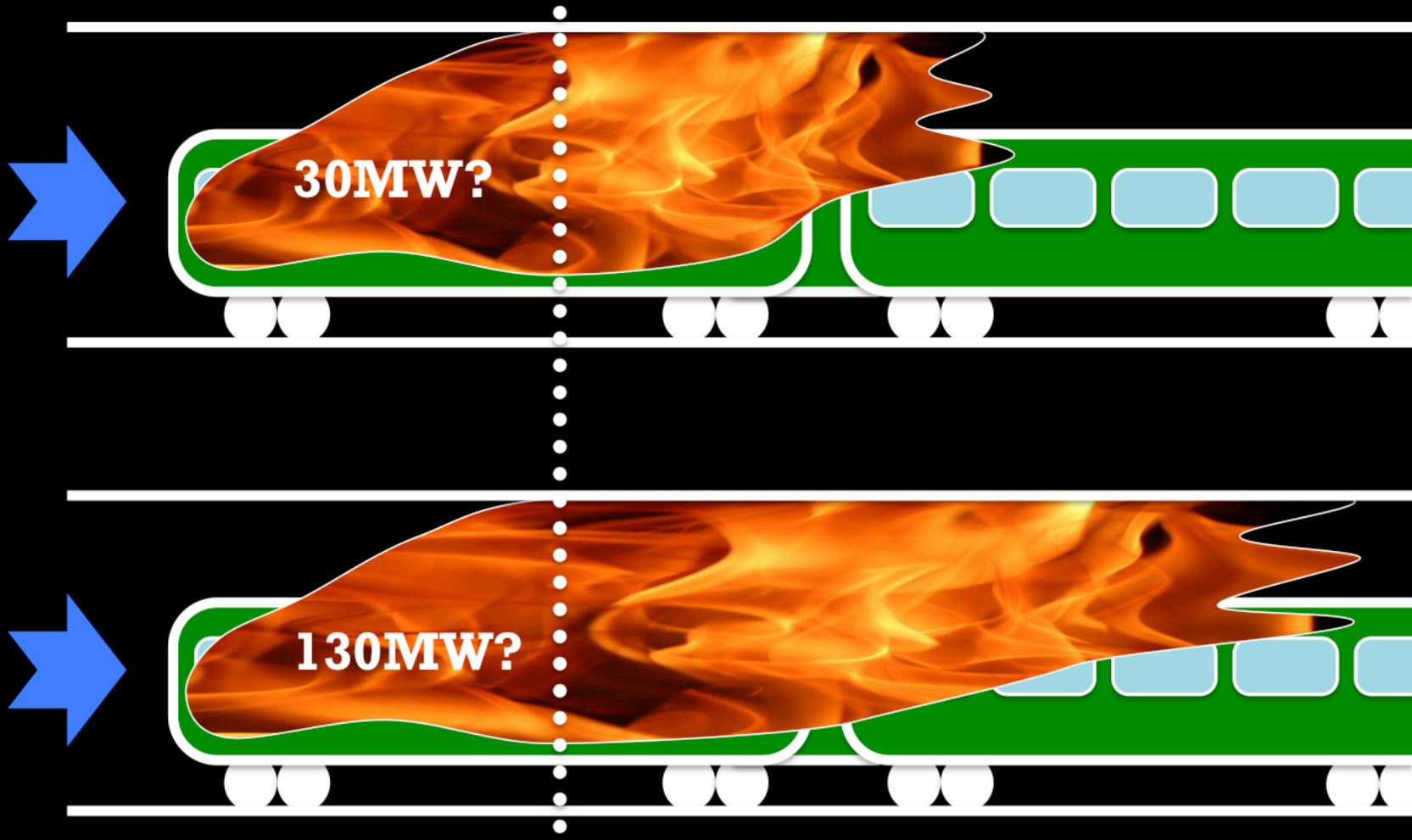
Large, short duration fire

Which is better…

…for life safety?

…for structural protection?

Structural protection?



For the structure, fire duration is much more important than fire size…

Recent research at Edinburgh:

Ventilation vs. Egress?

Options:

1. Do not ventilate
2. Minimise ventilation
3. Blow from one side (which side?)

What do you expect or instruct the passengers to do?

What do you expect or instruct these passengers to do?

Options:

1. Immediate self-rescue egress
   - Through smoky conditions?
   - Past the fire or away from the fire?
2. Wait until instructed to egress
   - Egress front of train, then reverse the ventilation direction?
   - How long will this take?
   - How smoke-tight is a train carriage?
   - Will people actually obey this instruction?

Trade-off #3

Ventilation vs. Stratification?

Trade-off #3

Ventilation vs. Stratification?

This is worse! According to our (preliminary) study, the passengers at the back of the queue are exposed to extremely untenable conditions

Whereas, according to our study, all passengers can safely escape in this scenario. Its unpleasant, but not untenable

M. Winkler "Strategies for egress from trains on fire in ventilated tunnels"
University of Edinburgh (IMFSE) Masters' Thesis 2014.
Publication in peer reviewed journals intended by the end of the year.

Trade-off #4?

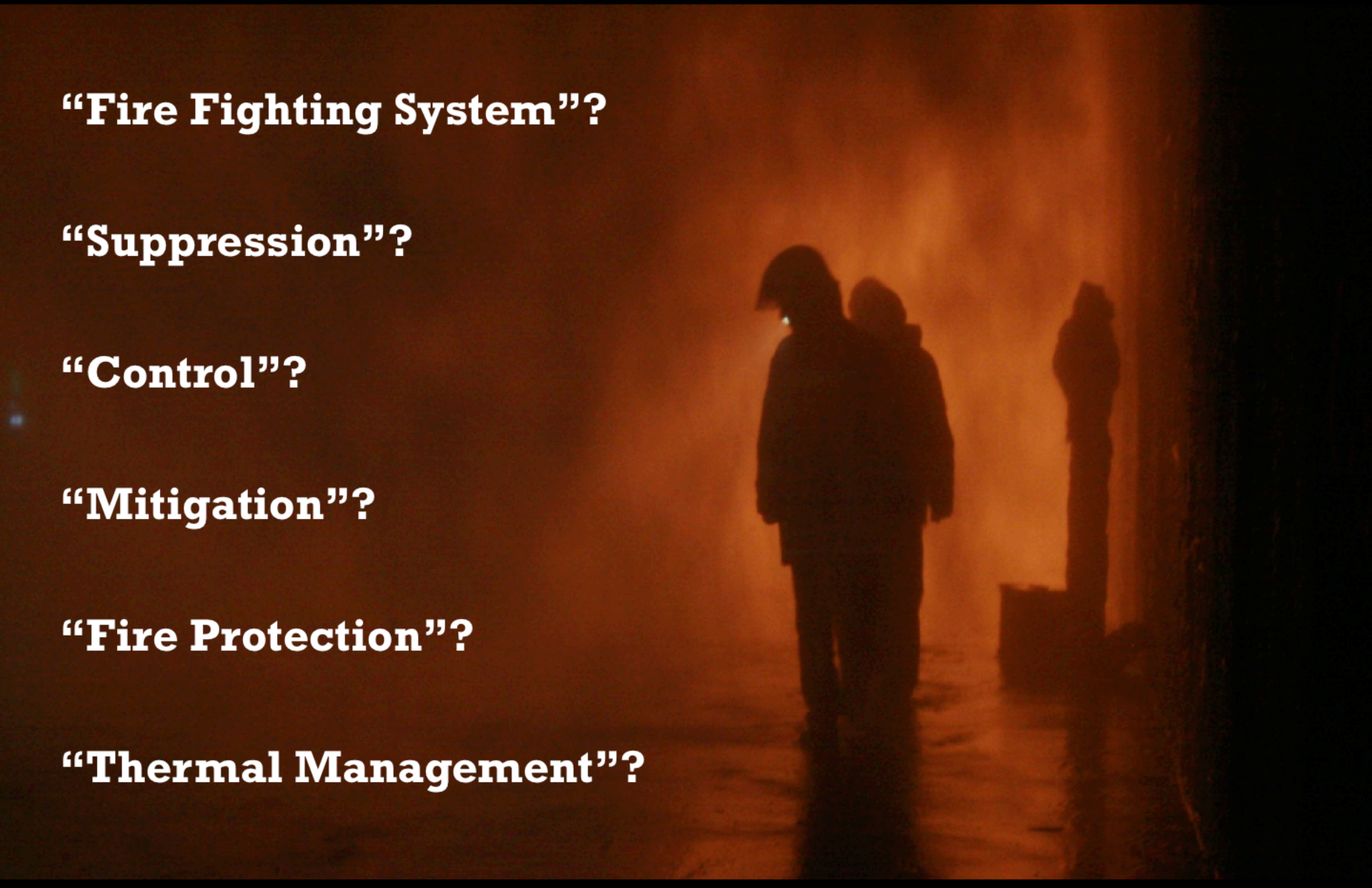
The current contentious issue in the tunnel fire safety industry:

Fixed Fire Fighting Systems

vs.

Structural Fire Protection

Fixed Fire Fighting Systems?



"Fire Fighting System"?

"Suppression"?

"Control"?

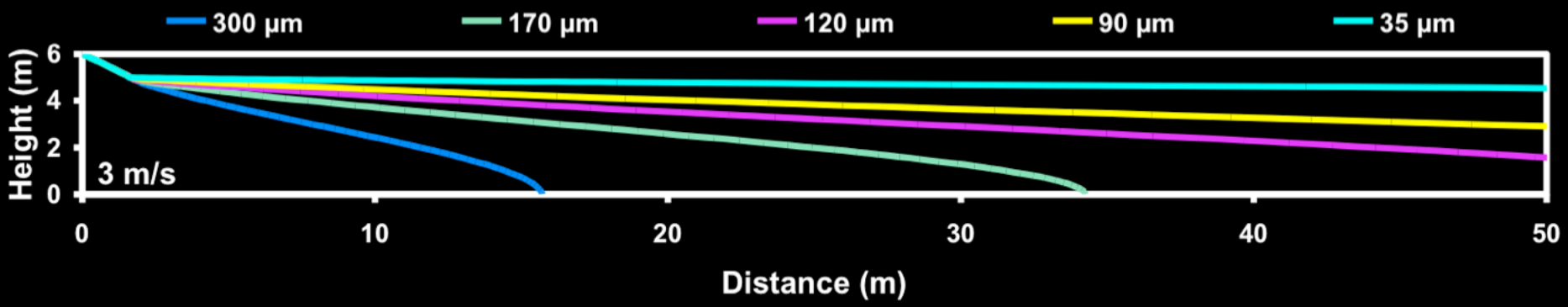
"Mitigation"?

"Fire Protection"?

"Thermal Management"?

Trade-off #5

Water Mist vs. Ventilation



(Rein, Carvel & Torero, 2008)

Maybe these systems can work together?

Back to Trade-off #4...

Fixed Fire Fighting Systems

vs.

Structural Fire Protection

Now that you have airbags in your cars, do you still wear seatbelts?

What don't we know now that we did know 40 years ago?

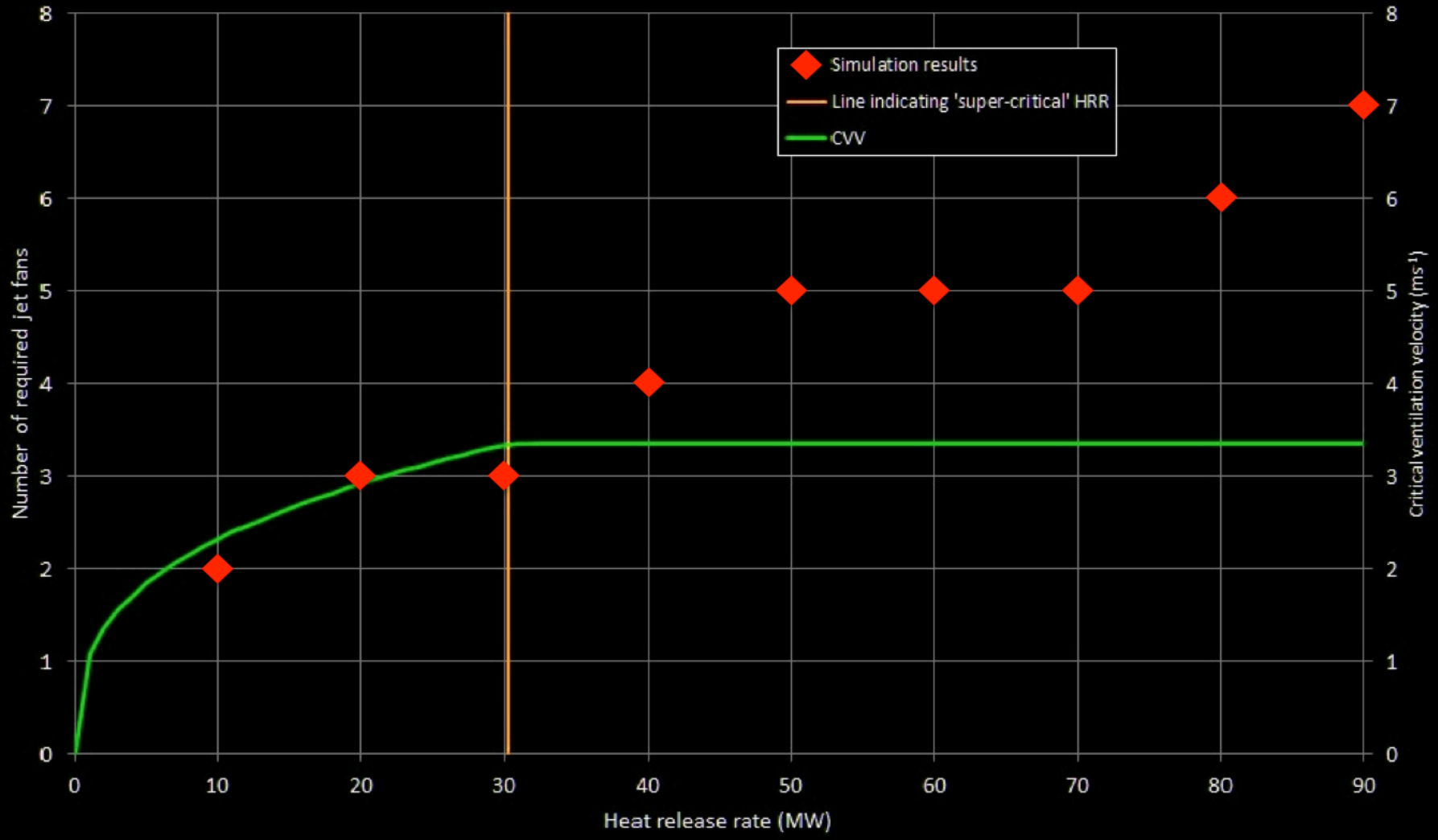
Trade-off #6

Ventilation Power vs. Fire Power

The 'Throttling Effect' was reasonably well known in the 70s.

We rephrased the question and then forgot all about it in the 80s

Trade-off #6



(Vaitkevicius, Colella & Carvel, 2014)


SP
Proceedings from the Sixth International Symposium on Tunnel Safety and Security
Marseille, France
March 12-14, 2014
Edited by Anders Lönnermark and Haukur Ingason
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DIPLOMA
This certifies that the paper
Rediscovering the throttling effect
by
Arnas Vaitkevicius, Francesco Colella and Ricky Carvel
Has been selected as
Best Paper at ISTSS 2014
Given this 13th day of March, 2014
Chairman Organizing Committee
Margaret Simonson McNamee
Chairman Scientific Committee
Haukur Ingason
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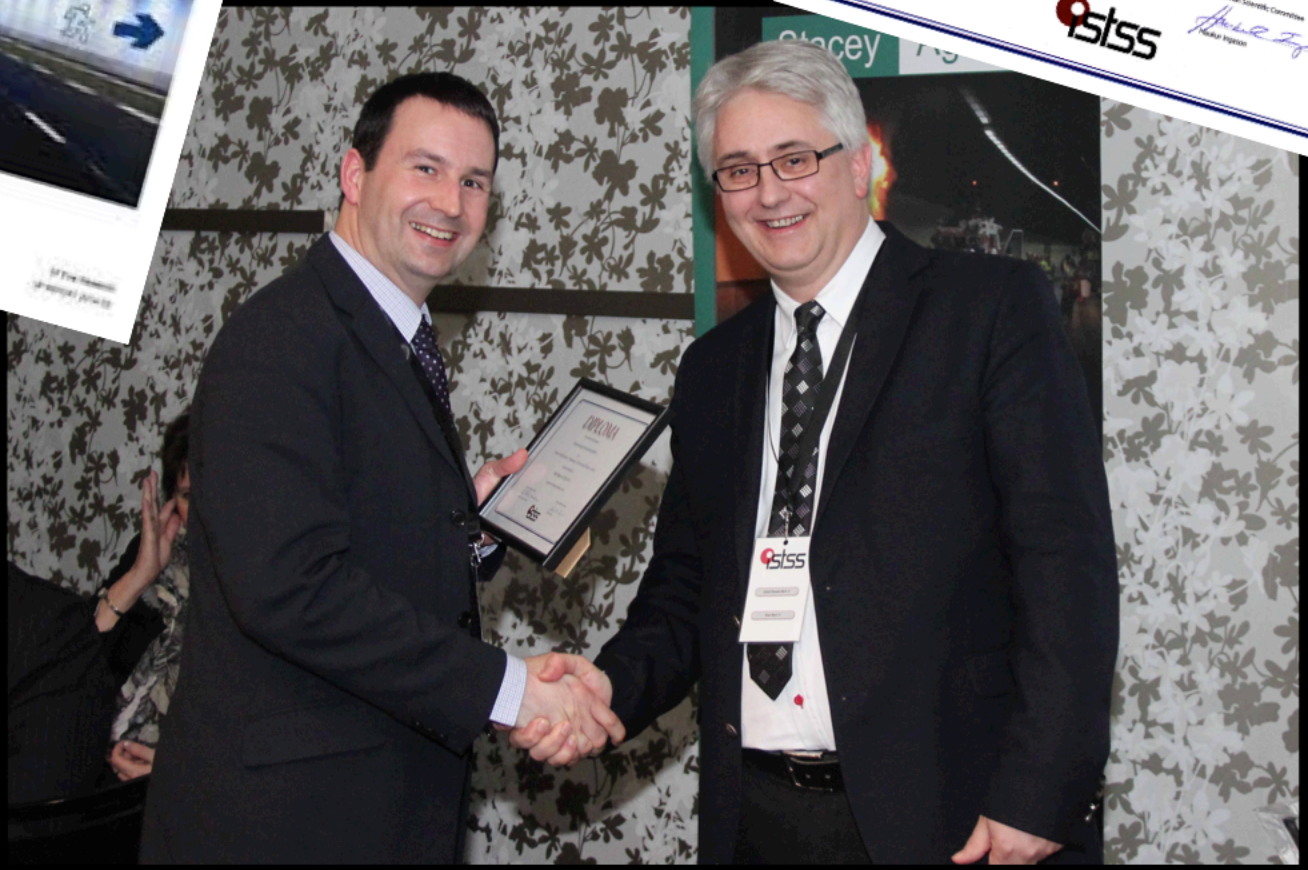
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Conclusions?

Tunnel fire safety is all about trade-offs

(you generally can't have your cake and eat it!)

Just because you have a system, doesn't mean you have to use it in any emergency…

(we still need to think about fire safety!)

Don't forget all the stuff we knew years ago

(but if everyone else forgets it, publish, and you might win a prize)

Edinburgh students are still brilliant!

(but, of course, you all know that!)

http://tinyurl.com/tunnelfire