Critical of Critical Velocity – an Industry Practitioner's Perspective

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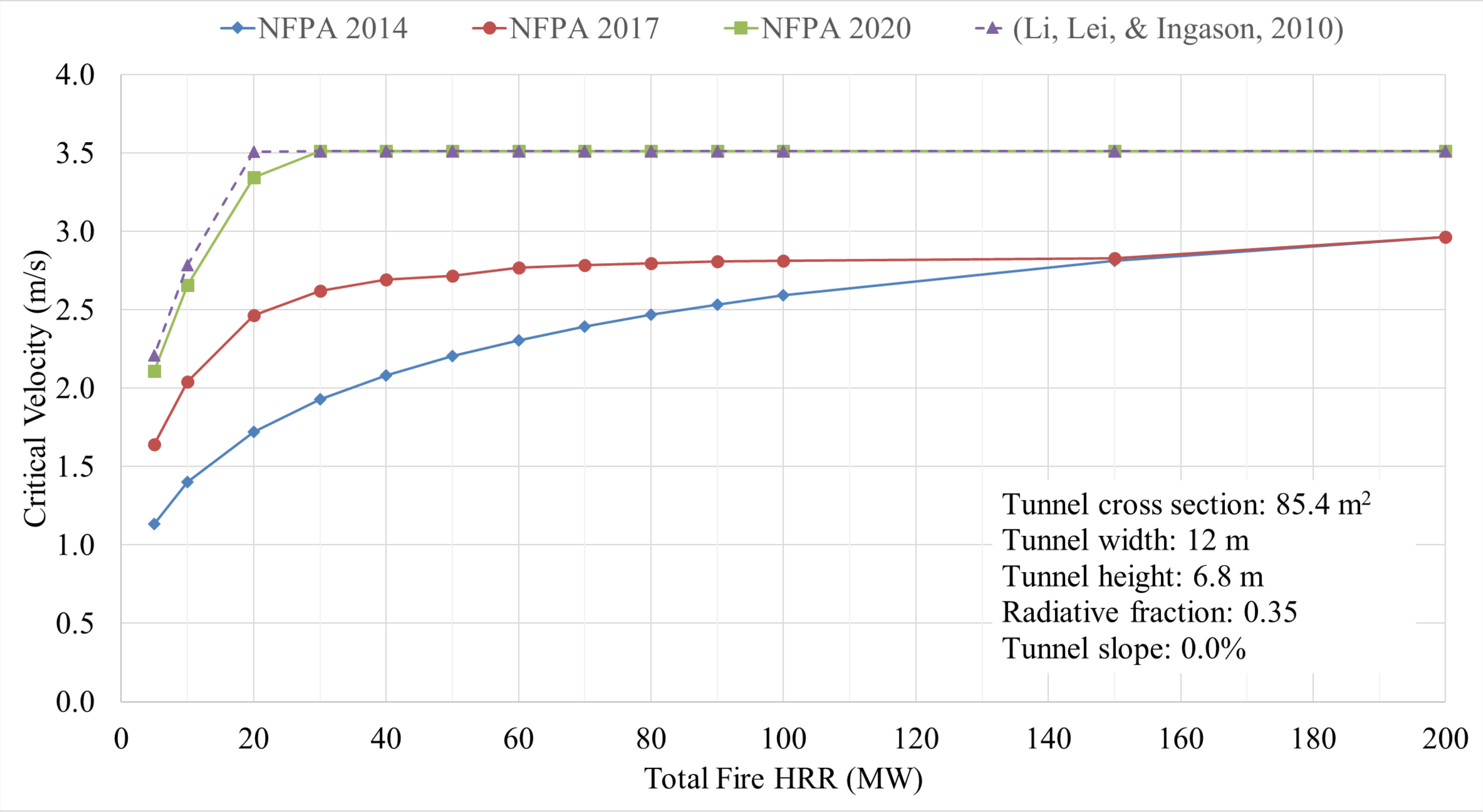
Two or more of these are wrong



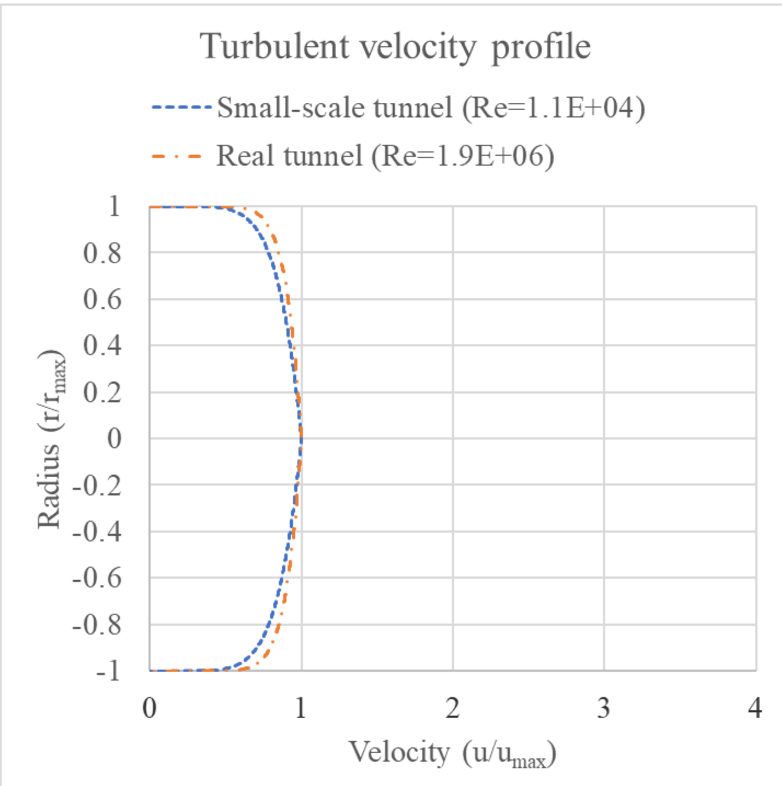
Problems with scale models of critical velocity

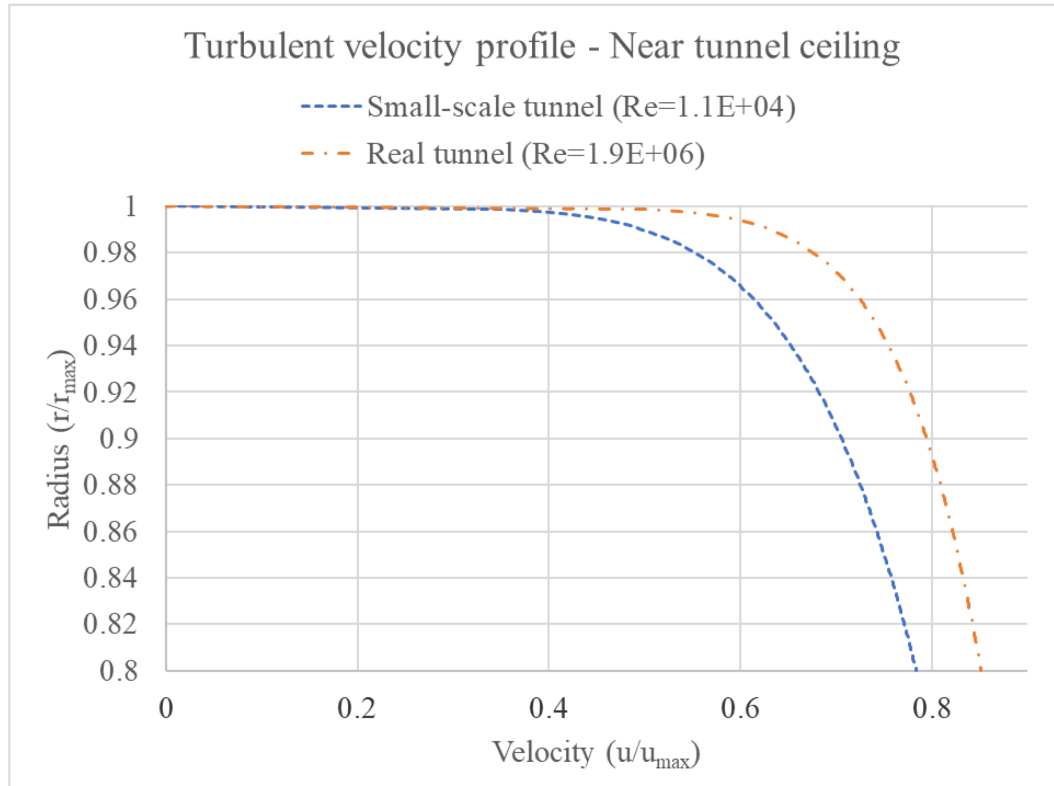
Only Fr used, and based on bulk (mixed) density change, not the smoke layer density or density difference.

But what about:

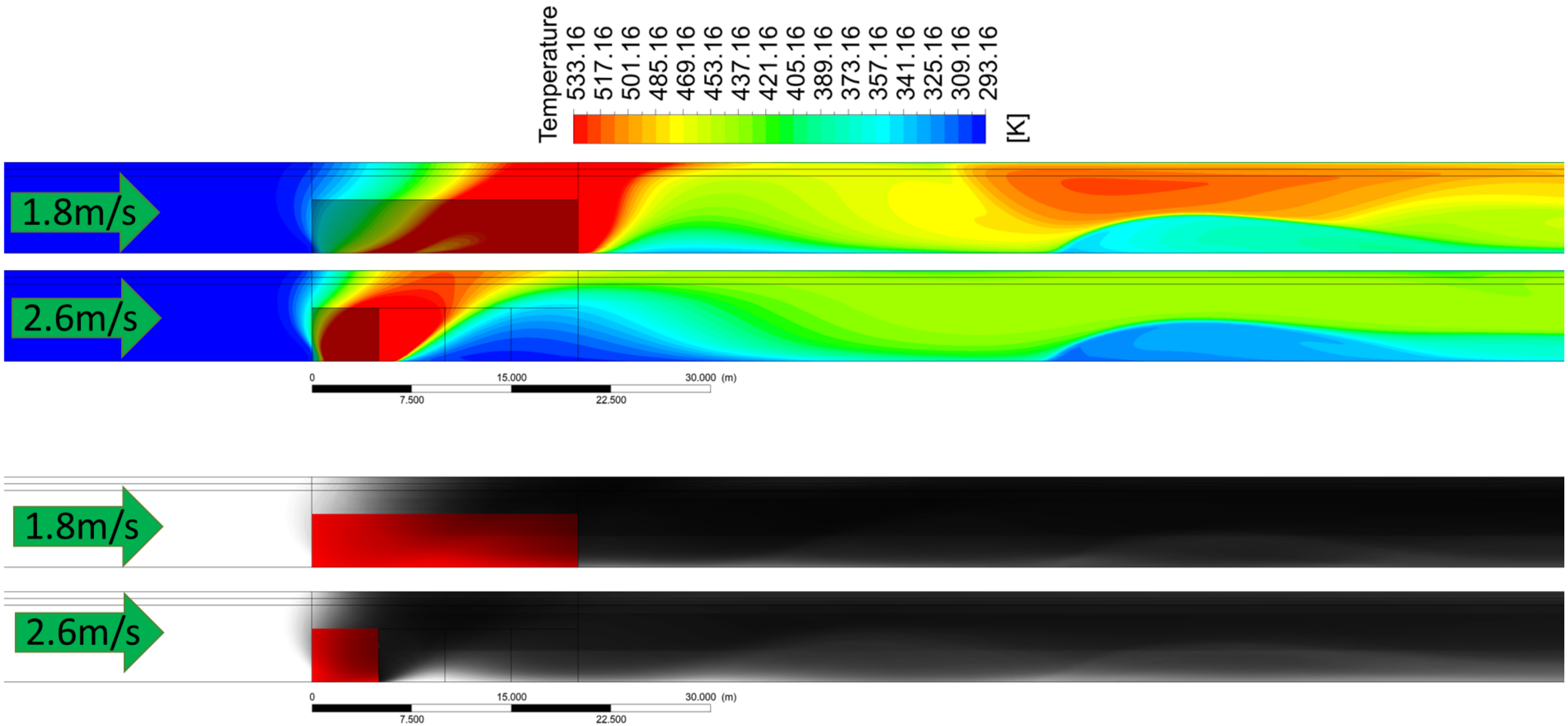
Re, Gr, Nu, etc…(in all the different flow regimes)
Fire intensity
Scaling with height

Reynold's number importance



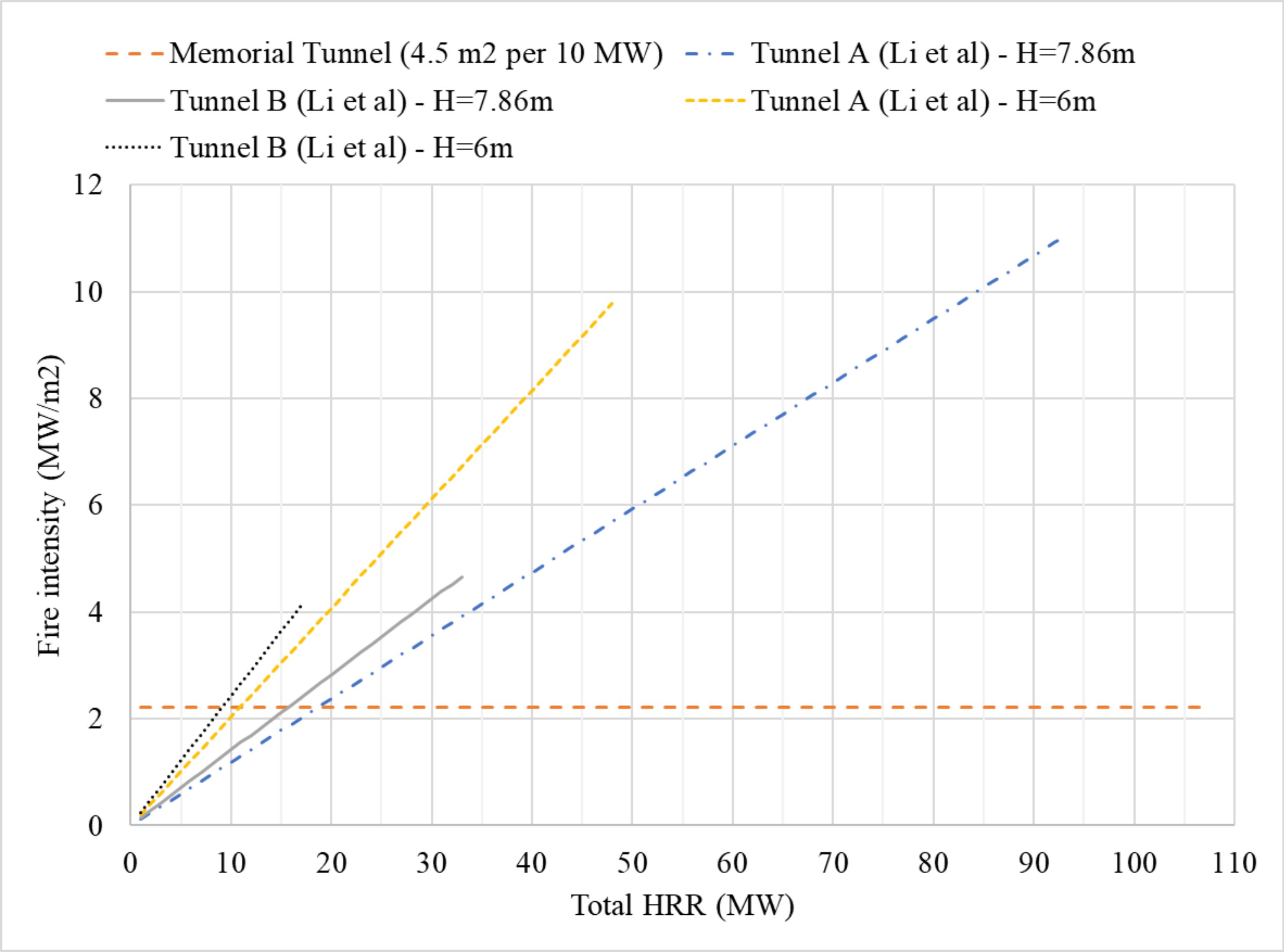


Fire geometry (and intensity) has a very strong influence on V_{CRIT}



Both cases 50 MW Total HRR

Scale model fire intensity



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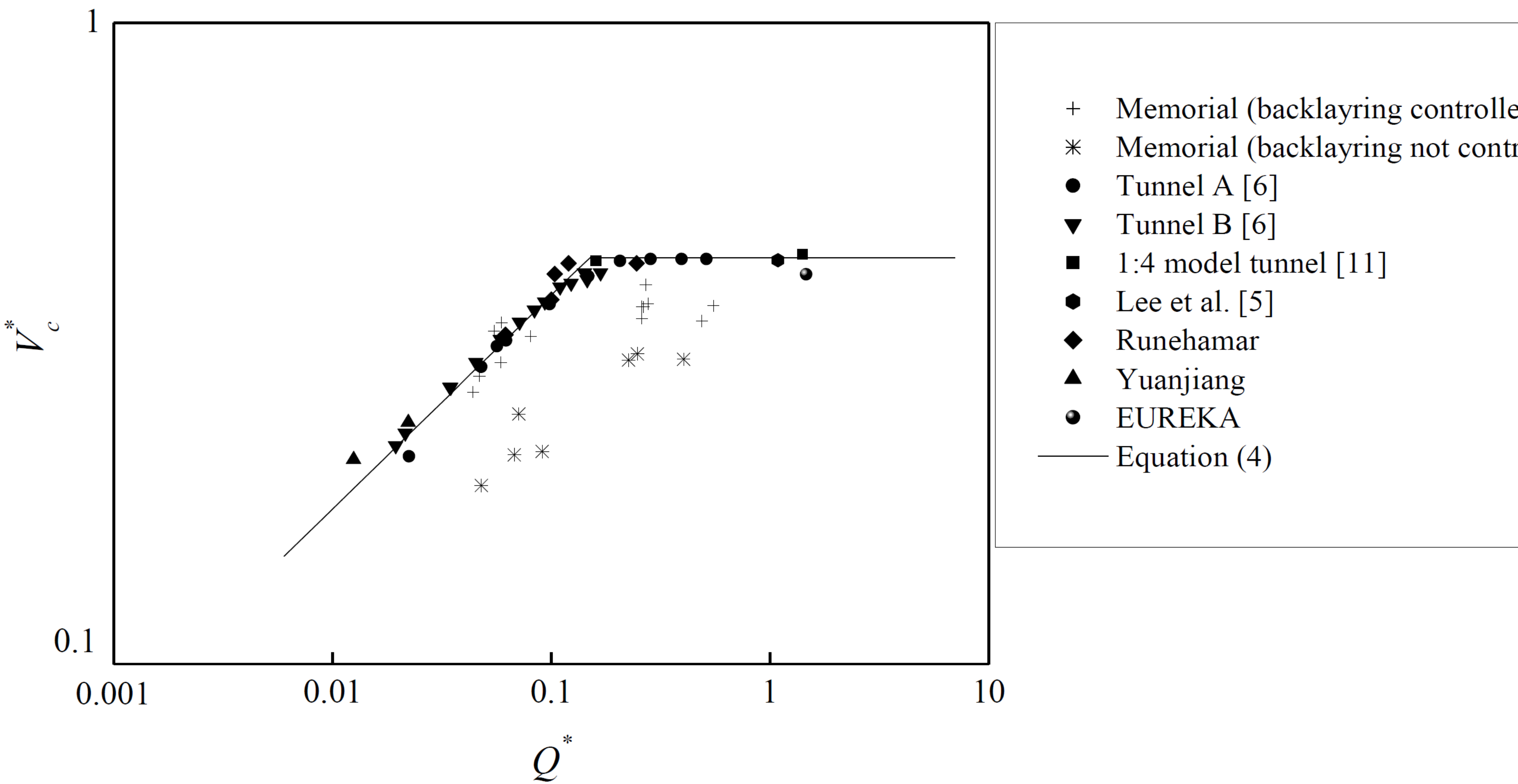
Summary on scaling from 1:20$^+$ models

- There is no evidence that the applied simple scaling methods are valid for real tunnel design.
- There are many known physical reasons that make it vulnerable to error.
- It would be extraordinary if simple scaling could come anywhere near unifying results from tests that differ in scale by a factor of 20.

So it is not surprising to see, when we look at the data, that the scaling simply does not work for tunnel design.

Li & Ingason – untreated Memorial Tunnel data



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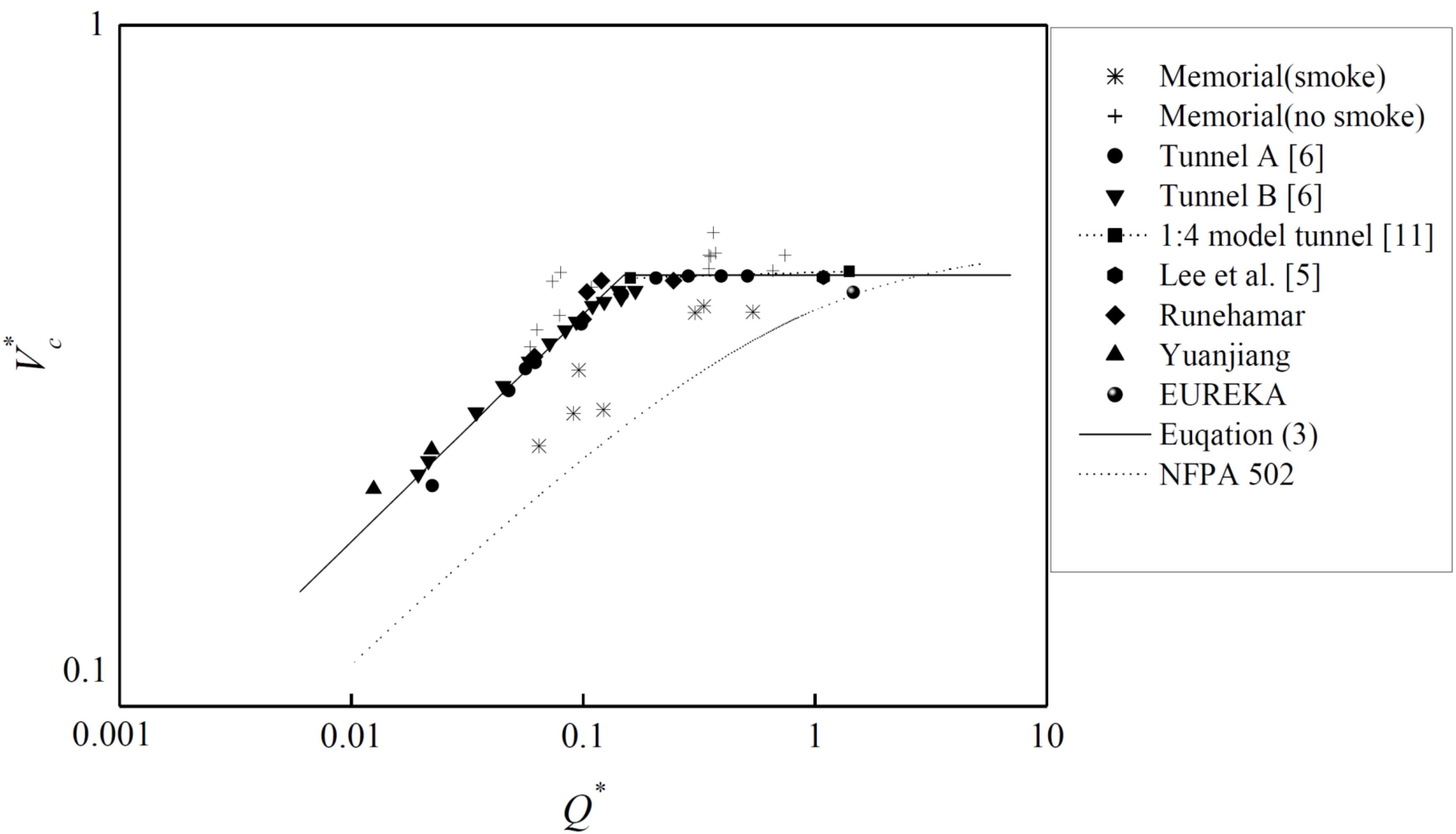
Li & Ingason – "corrected" Memorial Tunnel data



How the ”correction” was done (1)

“An average value of 35.5 m upstream of the fire source was used to predict the actual critical velocity for the Memorial tunnel fire tests.”

That is not the full story. In fact, a <u>constant</u> 35.5 m backlayering “correction” was applied. So yes, the average was 35.5 m, but there was no variation as implied. The same treatment was given to all data, whether backlayering was controlled or not.

Data for which they wrote that backlayering was generally less than 12 m, were “corrected” assuming 35.5 m backlayering.

How the “correction” was done (2)

From Li, Lei & Ingason (2010): $Q^* = \frac{Q}{\rho_o c_p T_o g^{1/2} H^{5/2}}, \quad V_c^* = \frac{V_c}{\sqrt{gH}}$

H tunnel height (m)

The formula refers to tunnel height.

For V_C only (not for Q), Li, Lei & Ingason scaled by height above the fire pans for Memorial Tunnel data (but used full tunnel height for other data referenced).

That is not revealed in the paper, or in the resulting NFPA material.

When tunnel height is used, as per Li, Lei & Ingason’s paper (and NFPA502), the assumed backlayering required to achieve the data ‘shift’ becomes more like 60 m.

No dispute about the “correction”

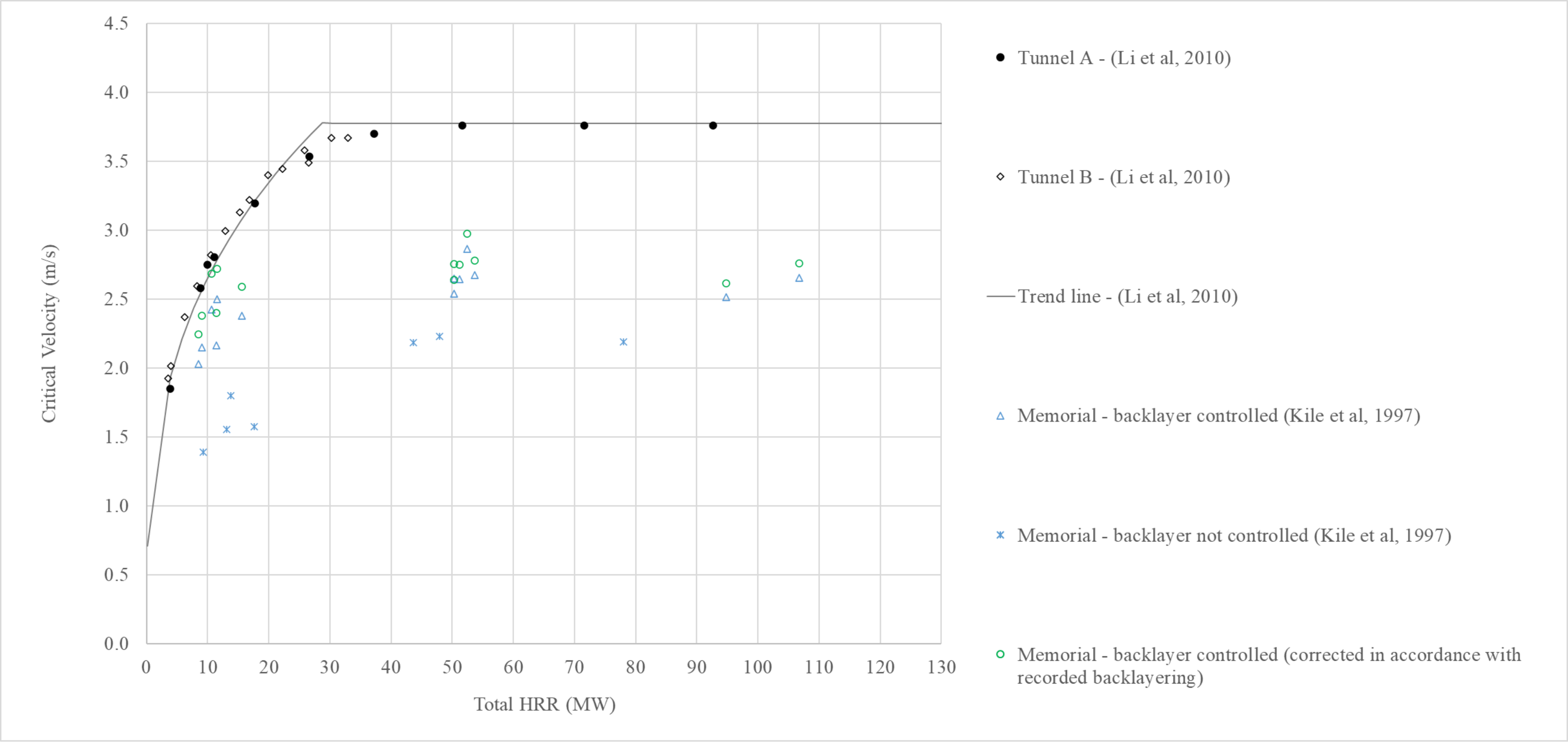
1. We noticed anomalies and reproduced the calculation ourselves.

2. Our spreadsheet was checked, amended and returned with comments by Li & Ingason in March 2020. This confirmed exactly their treatment of the data.

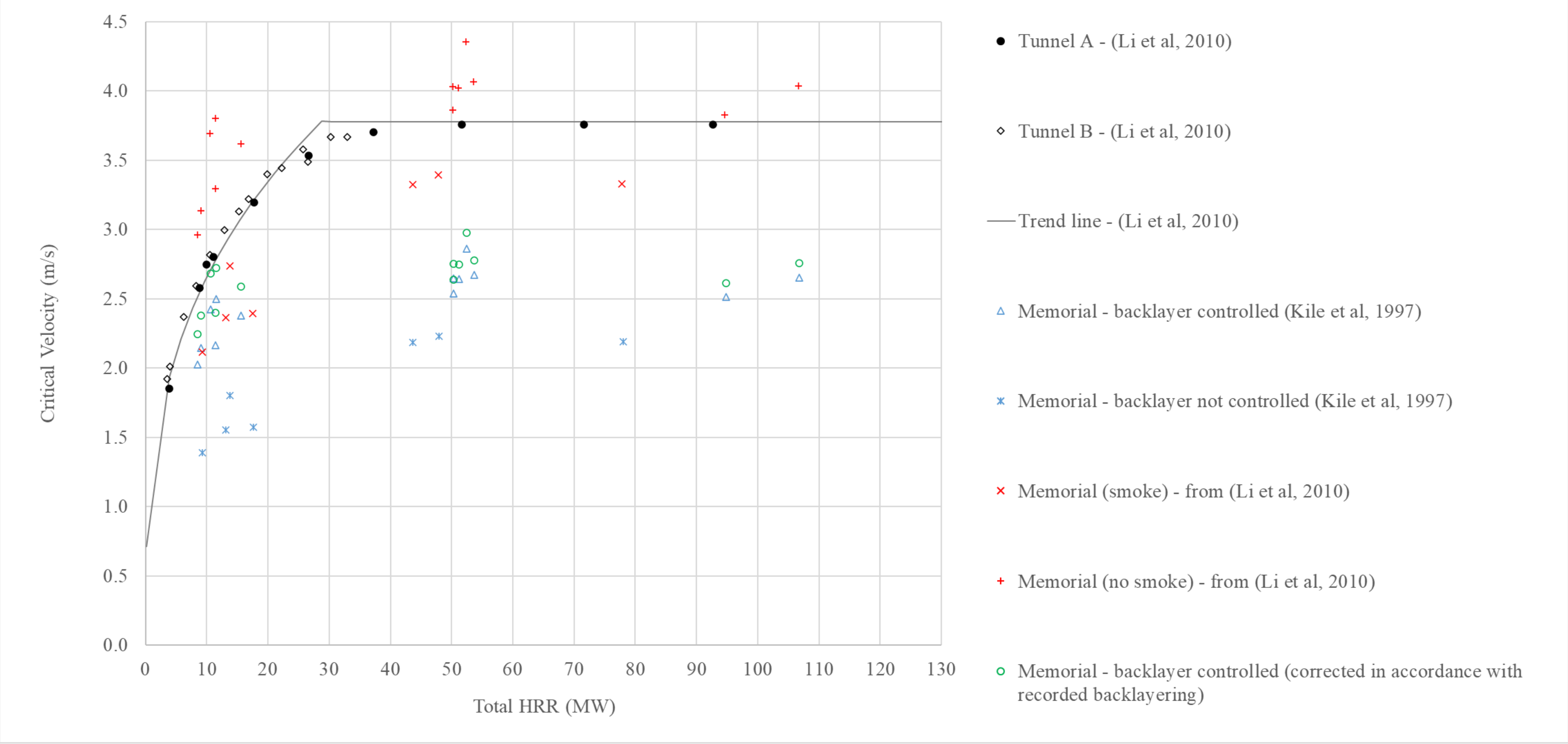
3. Ingason confirmed it to the NFPA 502 Working Group recently. They shifted the real data to where they were expecting it should be.

4. If you email us, we are happy to share the spreadsheet.

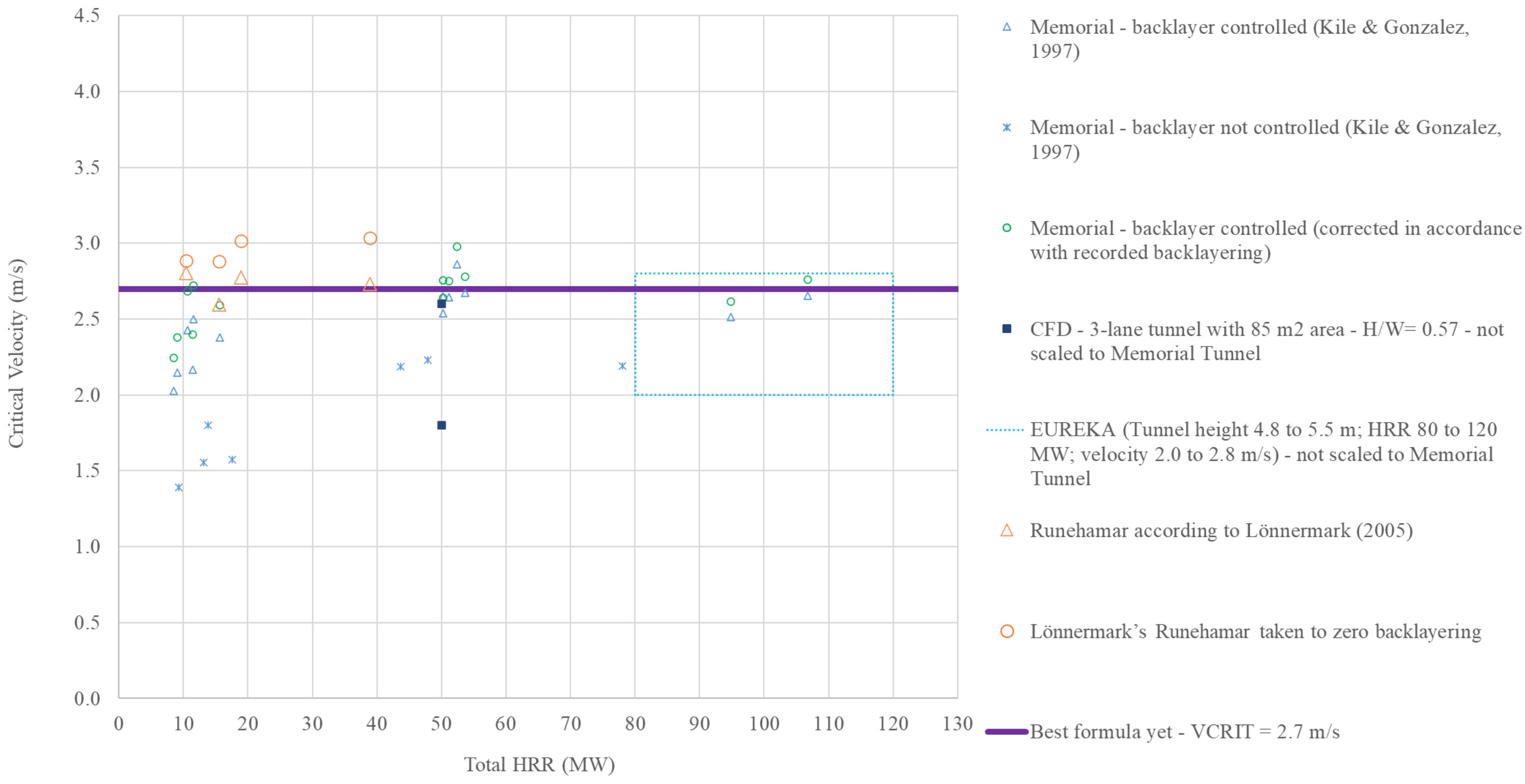
Memorial Tunnel data re-corrected, linear scale, real units



Memorial Tunnel data as Li and Ingason "corrected" them.

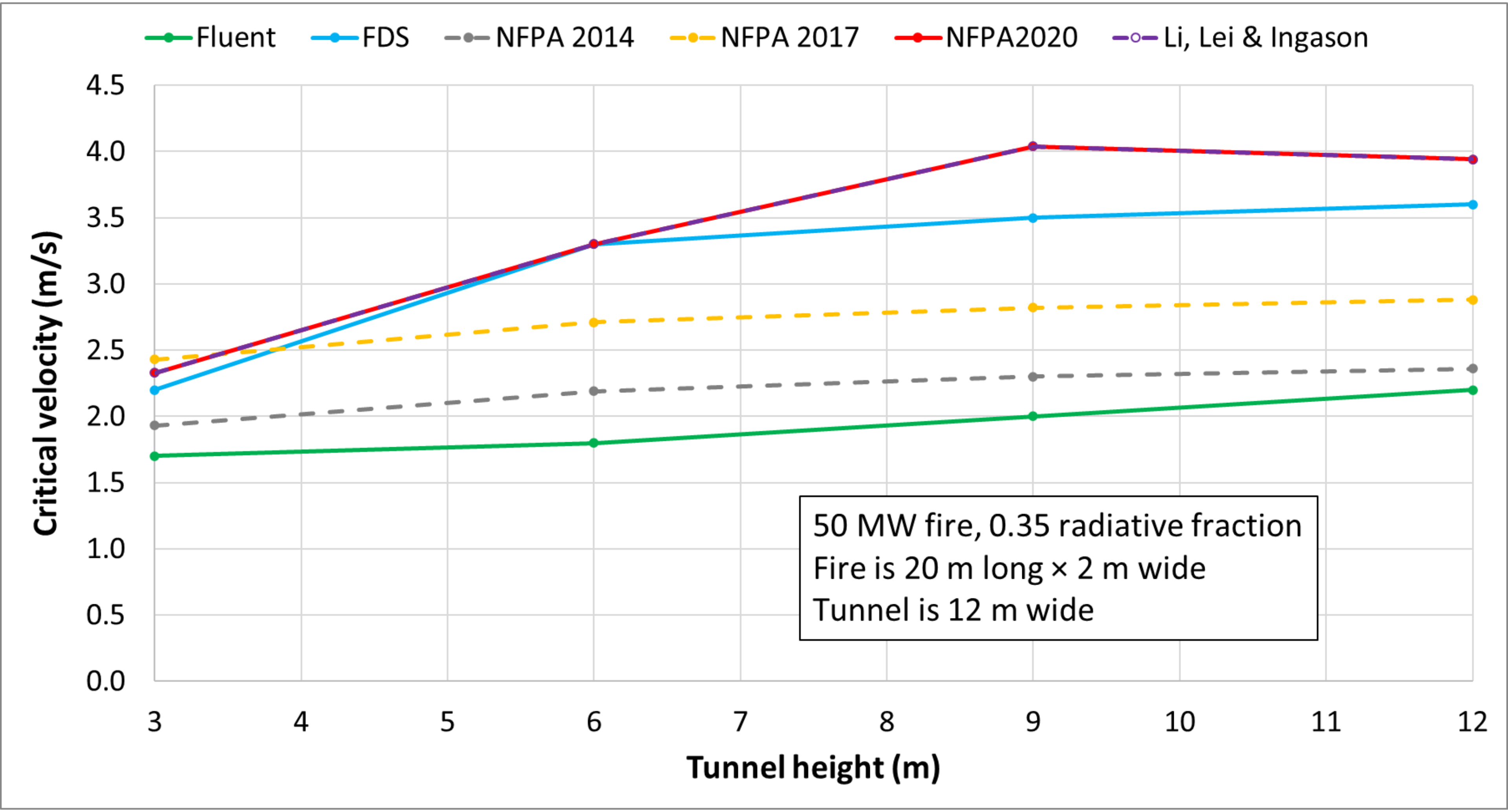


Treat the data fairly, put them on a linear scale with real units, and get the best formula yet; V_C = 2.7 m/s.



Where to now for critical velocity?

Do some CFD?



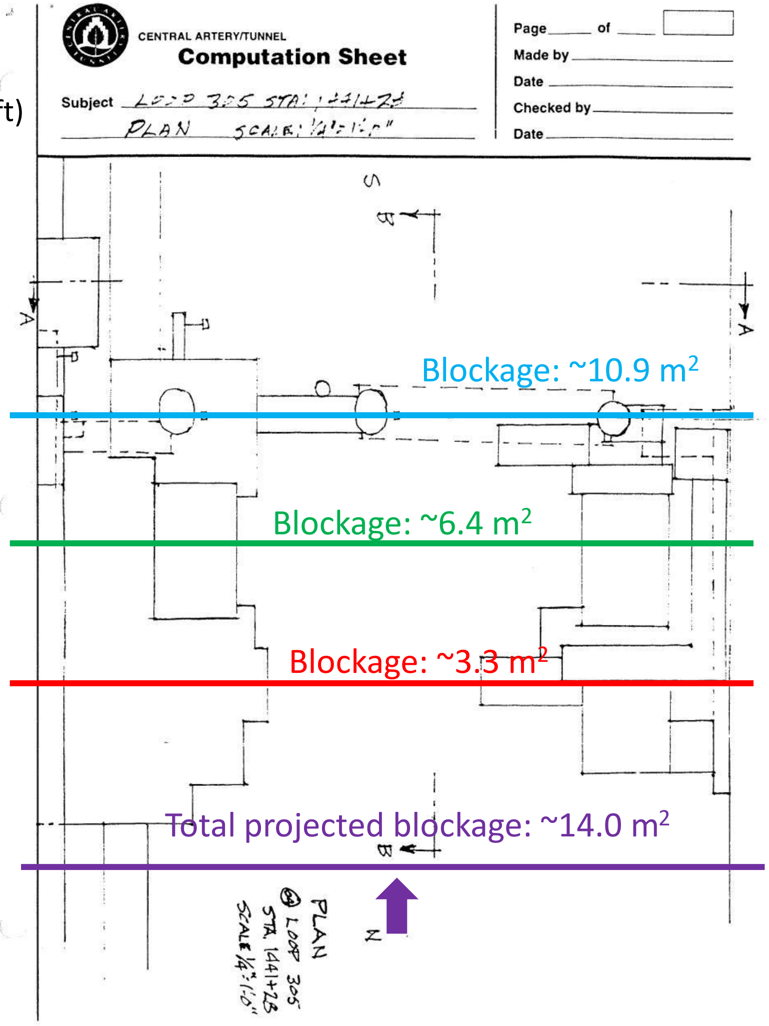
Fluent
FDS
NFPA 2014
NFPA 2017
NFPA2020
Li, Lei & Ingason
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Critical velocity (m/s)
3
4
5
6
7
8
9
10
11
12
Tunnel height (m)
50 MW fire, 0.35 radiative fraction
Fire is 20 m long × 2 m wide
Tunnel is 12 m wide

Look at blockage ratio?

Cross section area according to report: 36.32 m^2 (390 sq ft)
Cross section measured at Loop 305: 36.1 m^2
Cross section without false ceiling in place according to report: 60.53 m^2 (650 sq ft)

This is the photo WITH the ceiling.

Nothing to indicate that Kile & Gonzalez made a mess of the blockage ratio they applied to their case.



MEMORIAL TUNNEL FIRE VENTILATION TEST PROGRAM

COMPREHENSIVE TEST REPORT

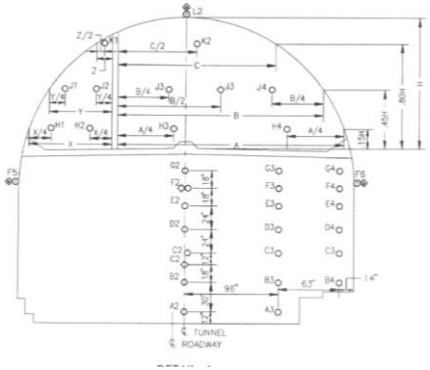
From Section 8.7.2, on the tests with the ceiling in place:

interval. Due to blockages such as insulation and the supporting instrumentation, the average local air velocity at Loop 305 was greater than the bulk air velocity. The local velocity was determined by dividing the bulk tunnel airflow by the net free cross-sectional area at Loop 305 (390 sq ft - 130 sq ft = 260 sq ft). **(This is 12.1 m^2, in line with our rough estimate.)**

From Section 8.8.4, on the tests with the ceiling removed:

fire centerline. Loop 305 was heavily insulated because of its proximity to the fire. The heavy insulation presented an obstruction to airflow which was estimated at approximately 110 sq ft or about 17 percent of the tunnel cross-sectional area. Therefore, the average local air velocity though the net free area (650 sq ft - 110 sq ft = 540 sq ft) was approximately 20 percent higher than the bulk air velocity which was based on the unobstructed tunnel area of 650 sq ft.

(Lower blockage area than with the ceiling in place.)



This indicates that Kile & Gonzalez correctly reflected the blockage ratio.

No justification for further adjustments is found.

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Conclusions

1. With the multi-physics involved, it is to be expected that simple Froude scaling would have strong limitations over a size factor of 2, let alone 20.

2. Li, Lei & Ingason "corrected" the Memorial Tunnel data to their expected outcome. There wasn't disclosure of that, and no justification has been offered. The real data show that their model experiments and trend differ widely from full-size tunnels.

3. We haven't seen, through the NFPA discussion process, any alternative justification supporting Li & Ingason's formula.

4. If it hadn't been adopted by NFPA502 (2020), no one would have noticed or been bothered.

5. The answer is 2.7 m/s, why make it more complicated?

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Thank you