BMFE-08 Biarritz, France, 4-5 March 2020

PRESENTATION OF AN EXPERIMENTAL STUDY OF A MOTORCOACH TIRE FIRE

STUDIES OF REFERENCE

- **Experimental study of tenability during a full-scale motorcoach tire fire**
  Erik L. Johnsson & Jiann C. Yang (NIST)
  published in Fire & Materials 2019;43-131-143

and

- **Motorcoach Tire Fires – Passenger Compartment Penetration, Tenability, Mitigation, and Material Performance**
  Erik L. Johnsson & Jiann C. Yang
  National Institute of Standards and Technology
  Gaithersburg, MD, USA

IN SHORT

- Setup: Original rear of the motorcoach was complemented by a constructed front to recreate a realistic passenger compartment volume, and the interior was partially furnished to provide fuel for fire spread

- Scenario:
  1. Tire fire due to frictional heating of wheel metal
  2. The fire then spreads through a window
  3. Ignition of the installed contents
  4. Fire growth within the passenger compartment

- Goal: to determine the onset of untenable conditions due to the cumulative effects of heat and toxic gases

- Detailed experimental procedure can be found in the full report

EXPERIMENTAL SETUP

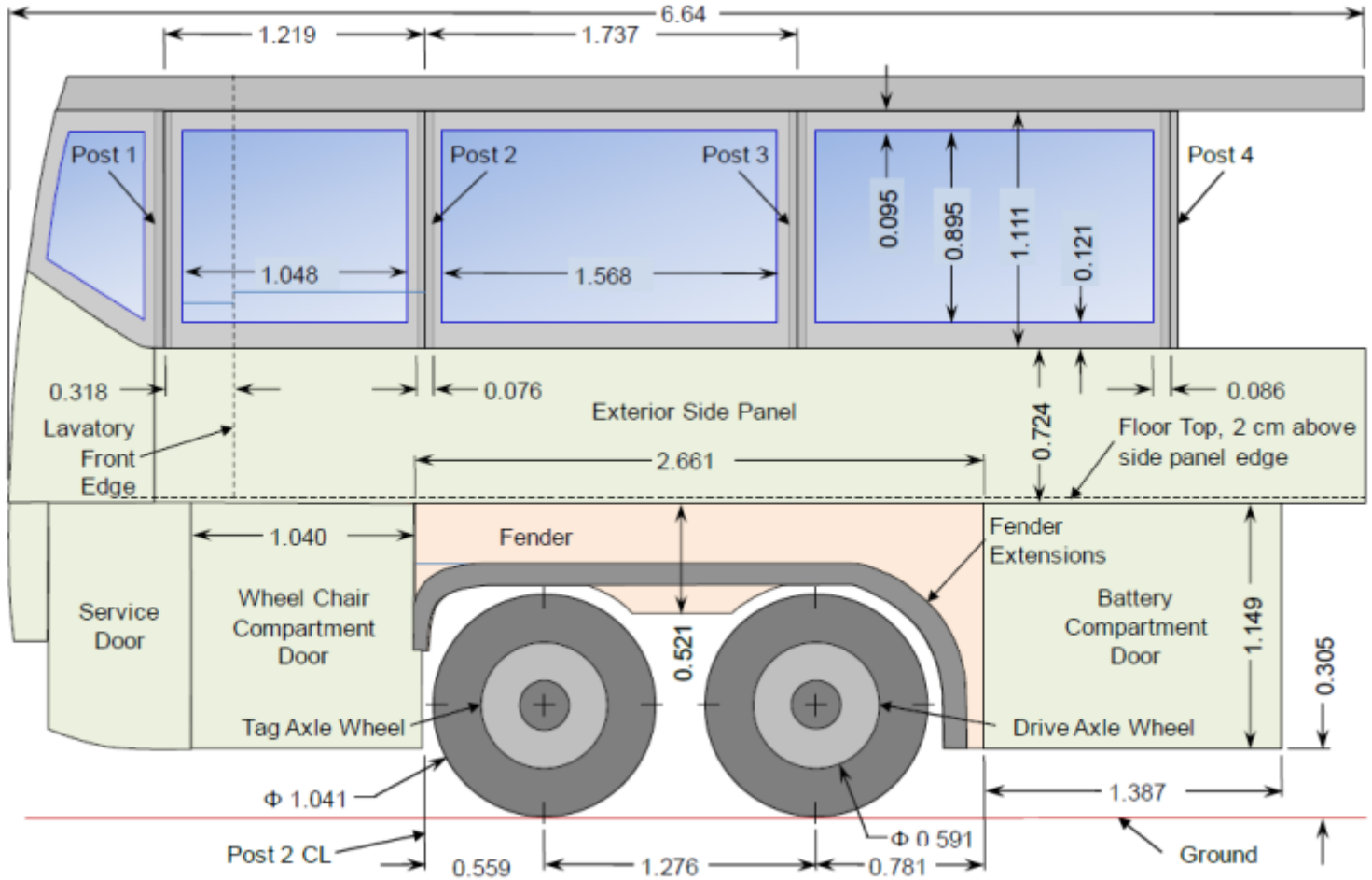


Figure 1 A drawing of the motorcoach rear half which was used for tire fire experiments. Dimensions are in meters. Distance measurement uncertainty is ± 0.3 %.

EXPERIMENTAL SETUP: IGNITION SOURCE

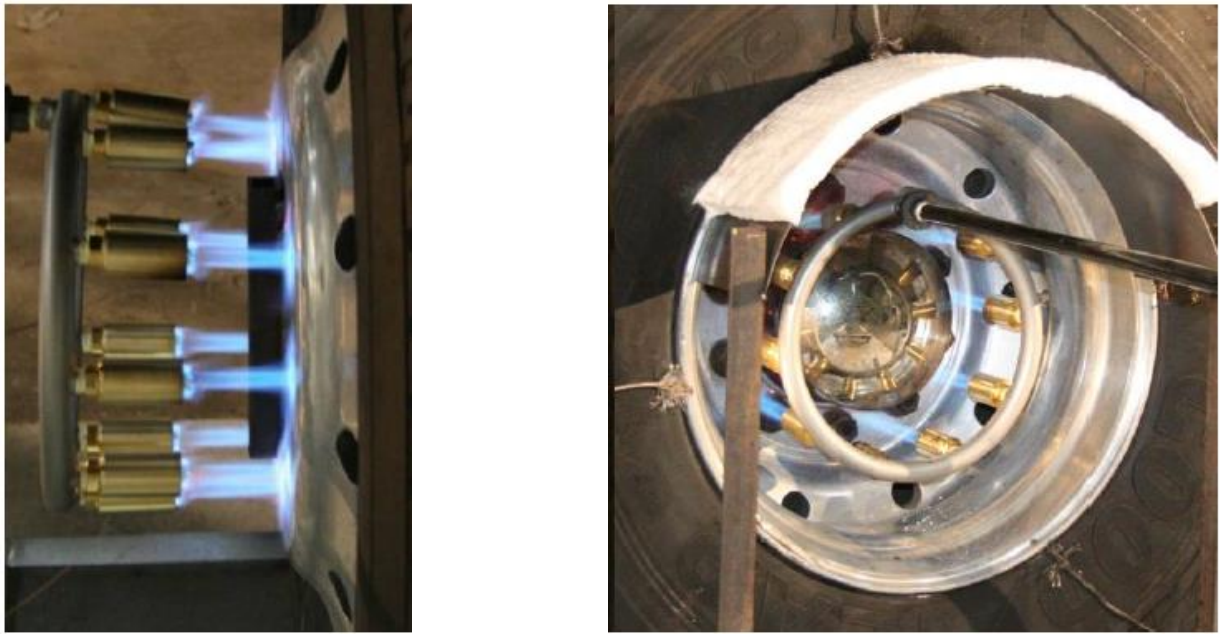


Figure 2 *(Left) A photograph showing the burner pre-mixed natural gas and air torches impinging on a tag axle wheel. (Right) A photograph showing the tire shield inside a drive axle wheel rim with an insulating cover to minimize heating from the shield to the tire.*

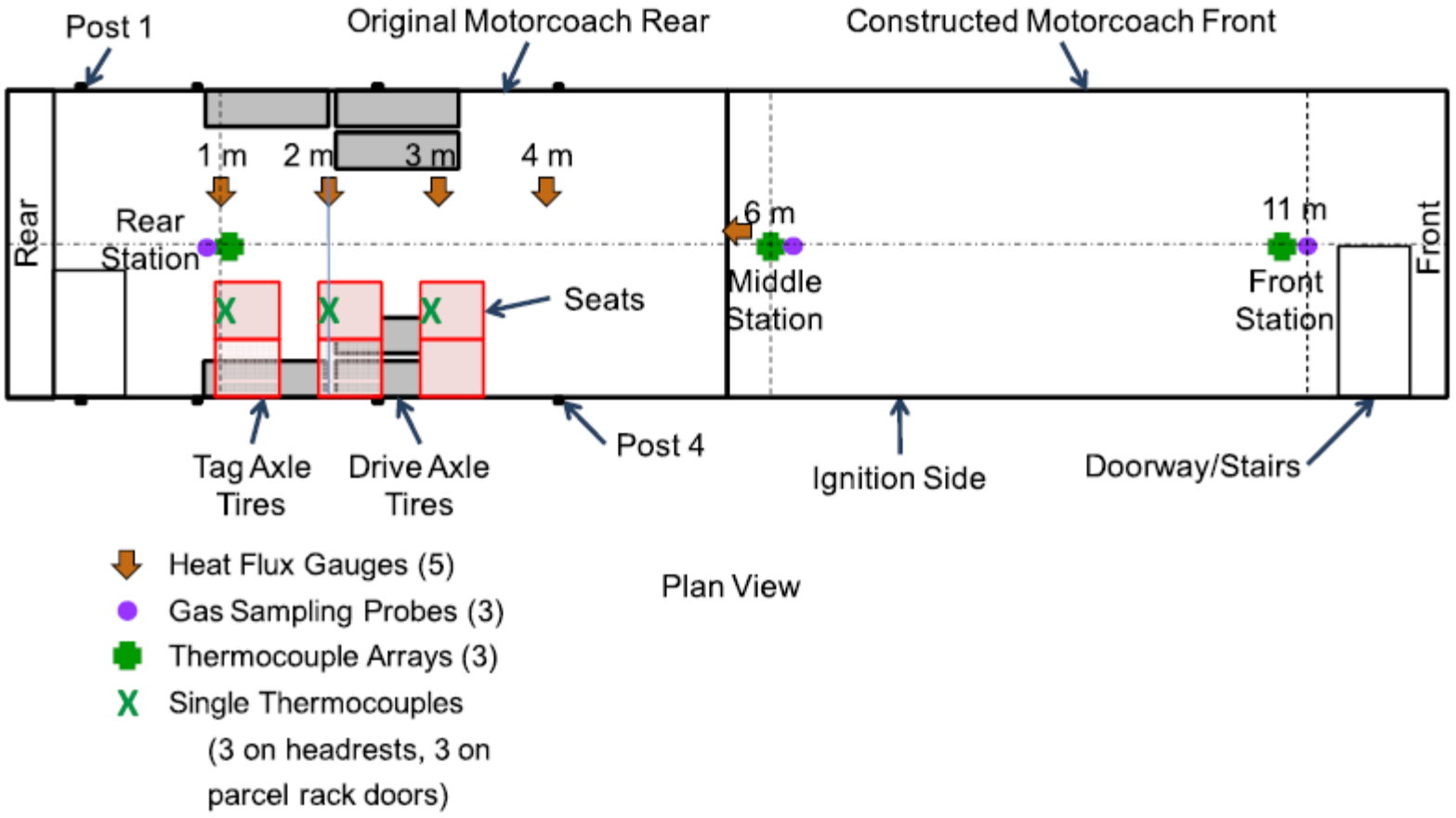
EXPERIMENTAL SETUP

- The constructed front of the motorcoach consisted of a wood frame structure upon which a steel stud frame was built and to which a galvanized sheet steel interior skin was attached
- The doorway matched that of an MCI E-series coach
- Original furnishings and trim components were reinstalled
- The components were required to pass the burner test prescribed in FMVSS 302
- The seats were composed of fabric over polyurethane foam

INSTRUMENTATION

- Temperature measurement:
  - 3 vertical thermocouple arrays (5 TC each) installed in rear, middle and front locations
- Heat flux measurements:
  - 4 HF gauges
- Gas volume fractions:
  - CO, CO2, O2 , THC, HCL, HCN
- Visibility:
  - smoke meter (laser + detector)
  - camera
- Calorimetry:
  - Heat Release Rate

INSTRUMENTATION



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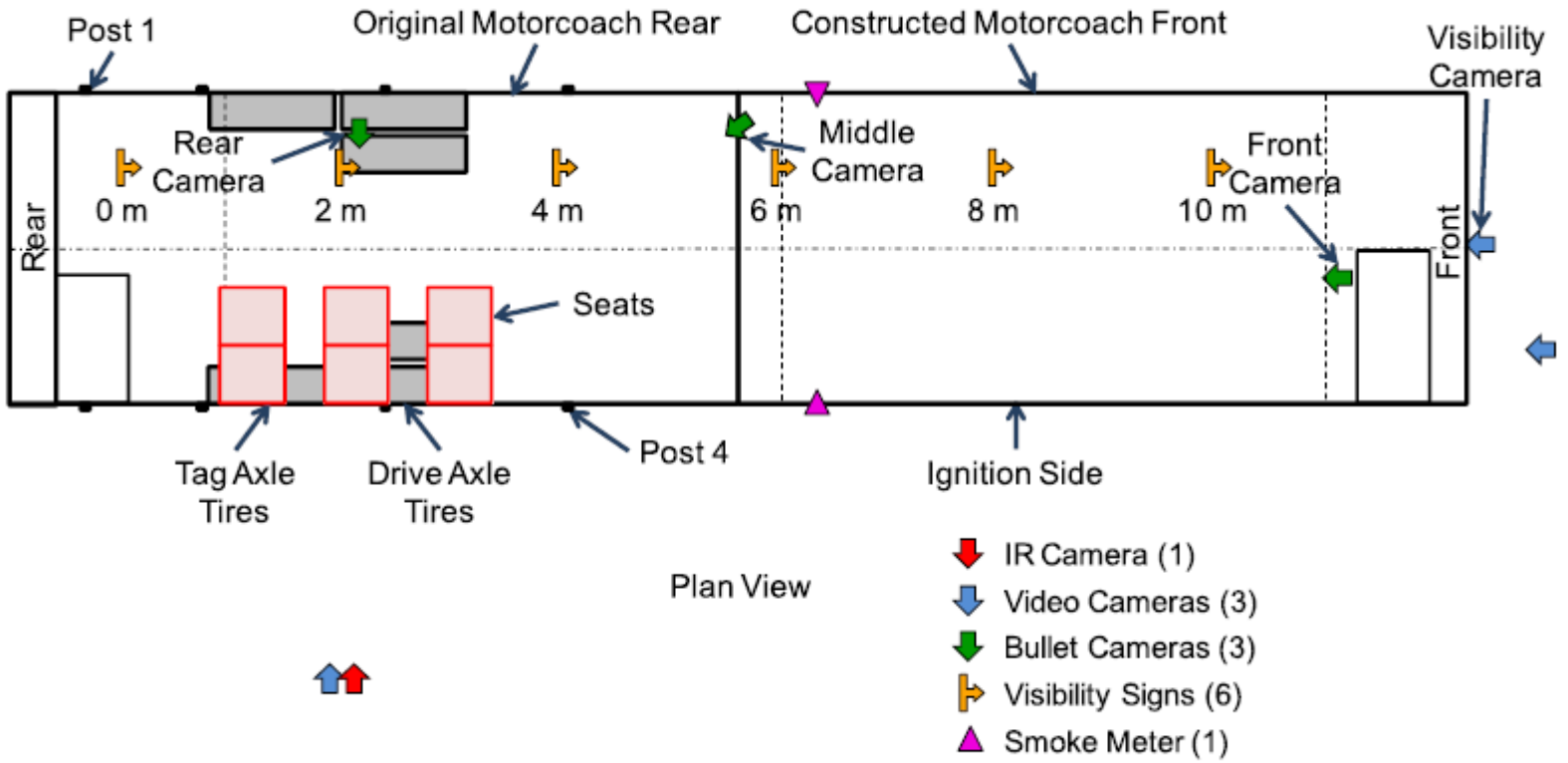

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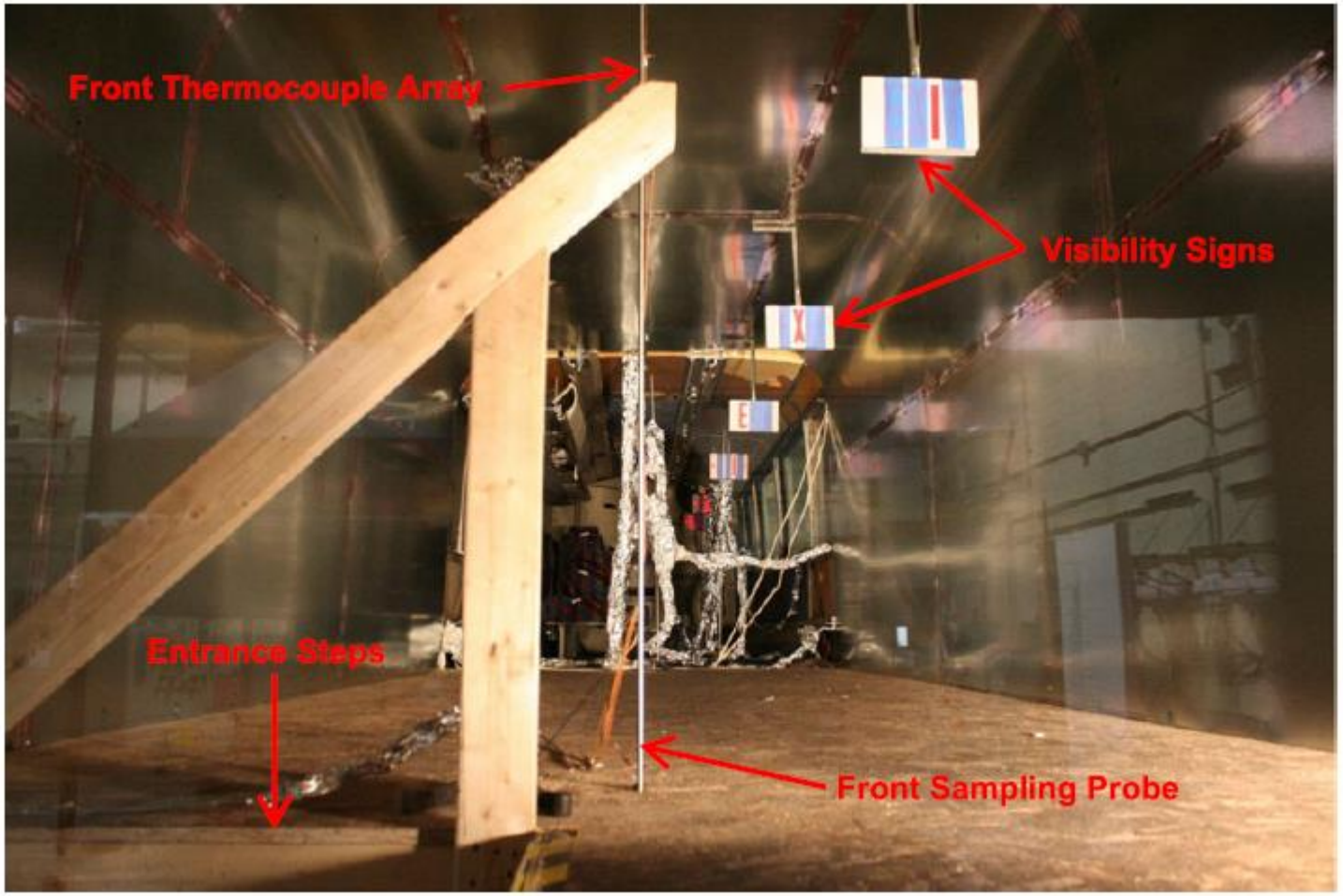

INSTRUMENTATION

RESULTS: TIMELINE

TABLE 2 Timing of events and observations during experiment (uncertainty = ±3 s)

Time, s	Event Description
−3450	Data recording initiated
0	Burner placed on wheel
720	Starting to see smoke from top of tire
1462	Cameras started
1800	Started FTIR
1832	A lot of smoke coming from under the back of the bus
2111	Small flame at 7 o'clock on the tire
2201	Tire ignited
2210	Burner removed
2232	Shield removed
2400	Fender ignited
2648	Glass broke
2861	Glass fell out and front of fender fell
2889	Flames in interior
2998	Seats on fire
3581	Suppression
4660	Visible flame in wheel well-suppressed

RESULTS: TENABILITY CONDITIONS

Tenability analysis

- ❑ Thermal = radiative + convective
- ❑ 2 models: fully clothed or lighly clothed occupants

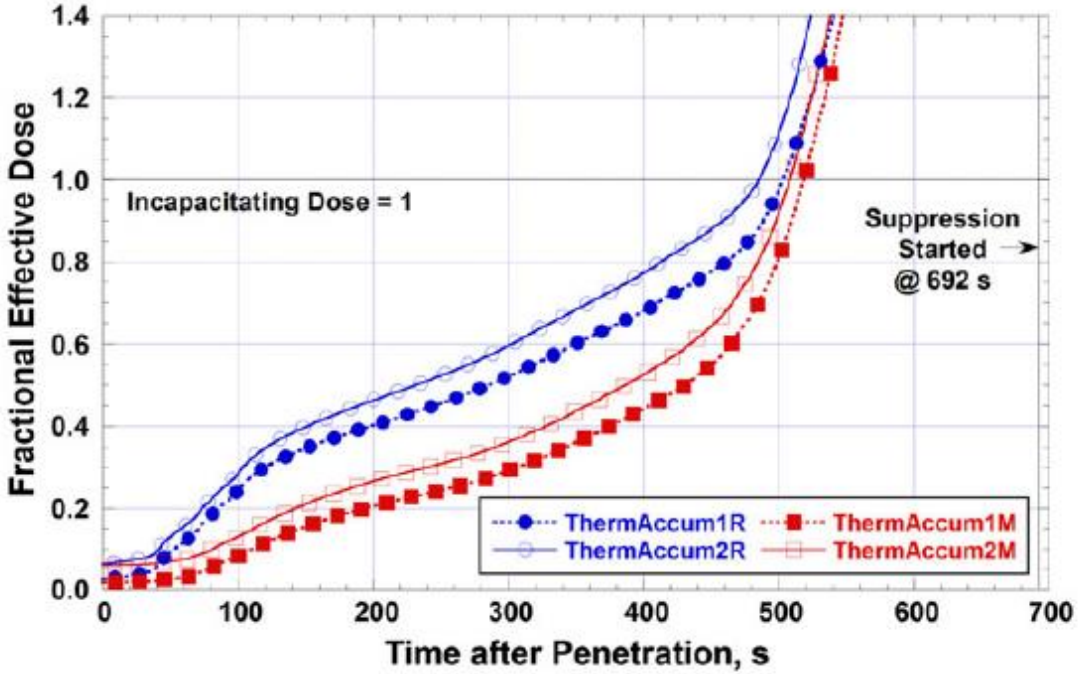

FIGURE 15 Fractional effective doses from combined radiation and convection plotted versus time after penetration for the rear (1-m) and middle (6-m) heat flux gauges and thermocouples 1.5 m above the floor. The type 1 analysis treats occupants as fully clothed while type 2 is for more lightly clothed occupants with more skin exposure

RESULTS: TENABILITY CONDITIONS

Tenability analysis

- ❑ Toxicity models: asphixiants (FED) & irritants (FEC)

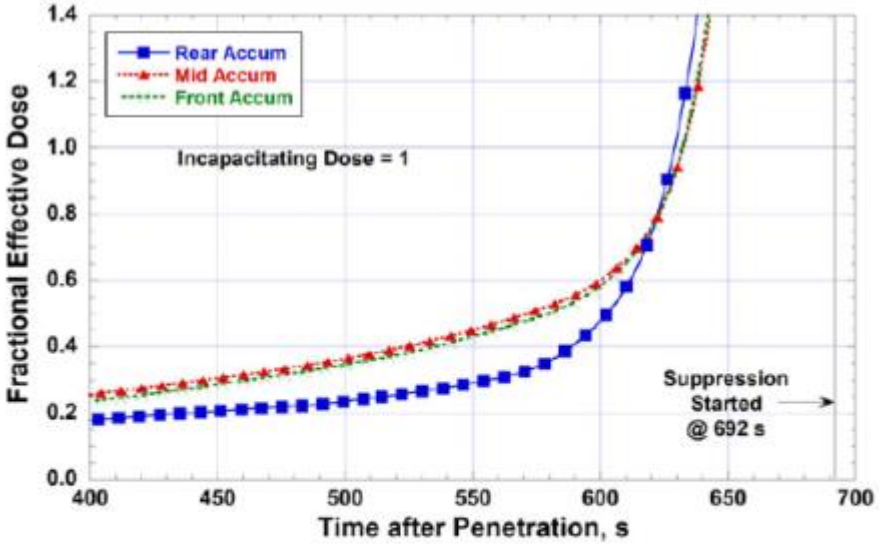

FIGURE 19 Total (both CO and HCN) fractional effective doses for the rear (R), middle (M), and front (F) sampling locations plotted versus time after penetration [Colour figure can be viewed at wileyonlinelibrary.com]

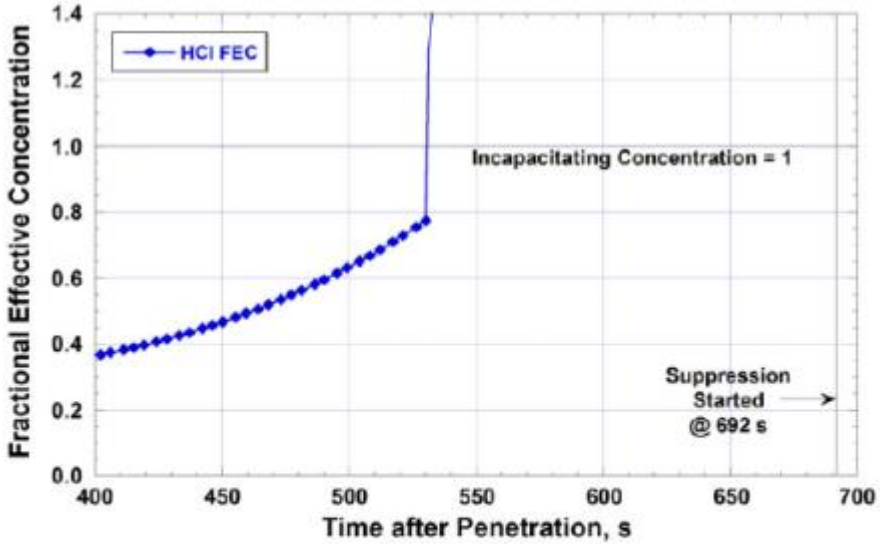

FIGURE 20 Fractional effective concentration for HCl measured with Fourier transform infrared spectrometer at the rear sampling location plotted versus time after penetration [Colour figure can be viewed at wileyonlinelibrary.com]

RESULTS: TENABILITY CONDITIONS

Location Hazard	Time from Fire Penetration to Untenable Conditions						
	Rear			Middle		Front	
	s		min:s	s	min:s	s	min:s
Radiative (heat flux)	511	3	8:31	522	8:42	N/A	N/A
Convective (temperature) fully clothed	641	8	10:41	675	11:15	676	11:16
Convective (temperature) lightly clothed	595	5	9:55	648	10:48	637	10:37
Combined radiative and convective (fully clothed)	503	2	8:23	518	8:38	N/A	N/A
Combined radiative and convective (lightly clothed)	485	1	8:05	508	8:28	N/A	N/A
Carbon monoxide (CO)	637	7	10:37	651	10:51	647	10:47
Hydrogen cyanide (HCN)	649	10	10:49	[a]649	[a]10:49	[a]649	[a]10:49
Combined CO and HCN	629	6	10:29	633	10:33	632	10:32
Hydrogen chloride (HCl)	531	4	8:51	[a]531	[a]8:51	[a]531	[a]8:51
Oxygen vitiation	642	9	10:42	659	10:59	654	10:54

[a]Levels assumed at locations (middle and front) other than where measured (rear).

RESULTS: VISIBILITY

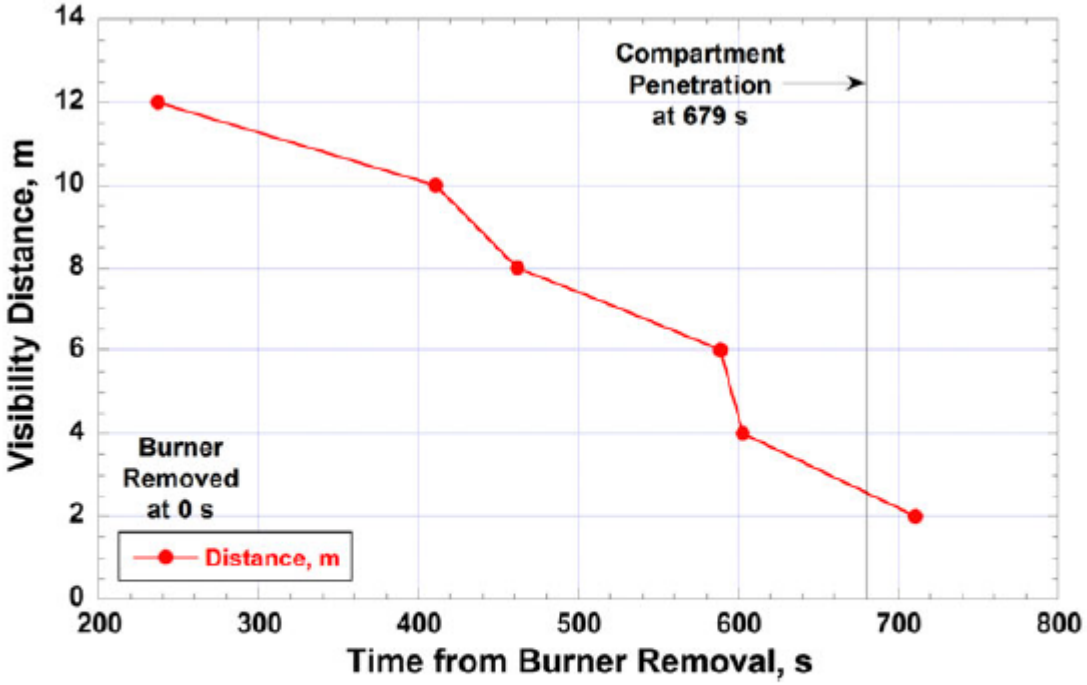

FIGURE 21 Visibility distance plotted versus the time from burner removal for the exit signs [Colour figure can be viewed at wileyonlinelibrary.com]

CONCLUSIONS

- A full-scale experiment with a partially furnished interior was conducted to investigate tire fire growth within the passenger compartment and the onset of untenable conditions
- Temperatures, heat fluxes, gas volume fractions, and visibility were measured and analyzed
- Thermal conditions were generally more severe at earlier times than toxic, irritant, or asphyxiant gas conditions
- Thermally untenable conditions were reached by about 8 minutes (rear and middle) after fire penetration
- CO and HCN combined to make conditions untenable just under 11 minutes after fire penetration, and HCl caused untenable conditions just under 9 minutes (rear) after fire penetration
- Visibility conditions deteriorated significantly prior to fire penetration: Within 30s after penetration, visibility decreased to less than 2 m
- The combination of three pairs of seats and partial trim installation was sufficient to cause flashover in the rear in less than 11 minutes after fire penetration

- Recommendations to BFME: If a real scale fire test is conducted, similar instrumentation is needed to evaluate tenability of occupants and time necessary to evacuate a bus
- Possibility to instrument such experiment at Efectis France