FLAMMABILITY STANDARDIZATION TASK GROUP UPDATE: Adhesives

Presented to: *Materials Fire Test Working Group*

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Objectives

Determine correlation between Microscale Combustion Calorimetry (MCC) properties and FAR flammability tests for stand-alone adhesives.

Approach

- FSTG members provide cured adhesive specimens and FAR vertical Bunsen burner (VBB) test reults:
  - 12 Second VBB
  - 60 Second VBB
- Conduct microscale combustion calorimeter (MCC) testing ASTM D 7309 at FAA on adhesives submitted by FSTG members.
- Correlate MCC flammability properties with FAR flammability (12s and 60s VBB) of adhesives.

Materials

3 companies participated in the study:

Magnolia

3M

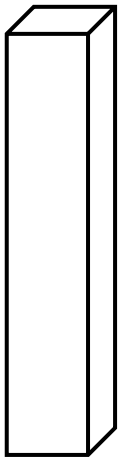
Gulfstream

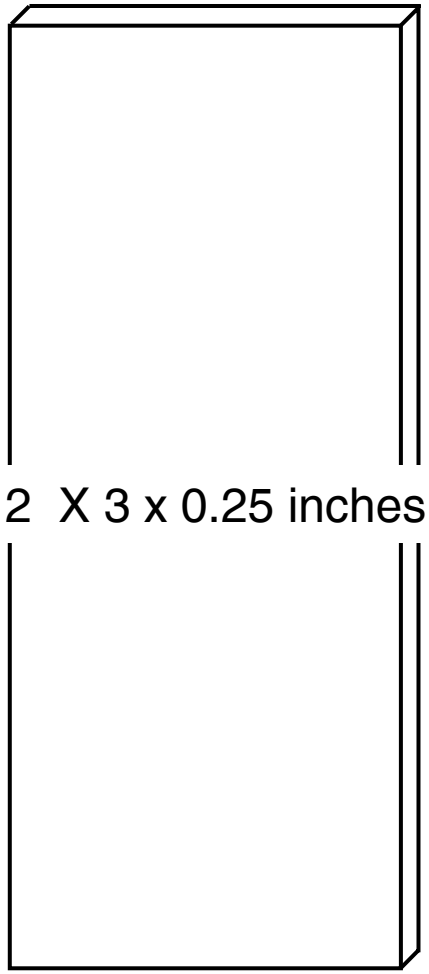
27 samples total were received for testing. 3 specimens with the same name were received from different suppliers.

25 samples came with results for 12s and 60s Vertical burn test from the supplying companies.

Specimens for VBB Testing

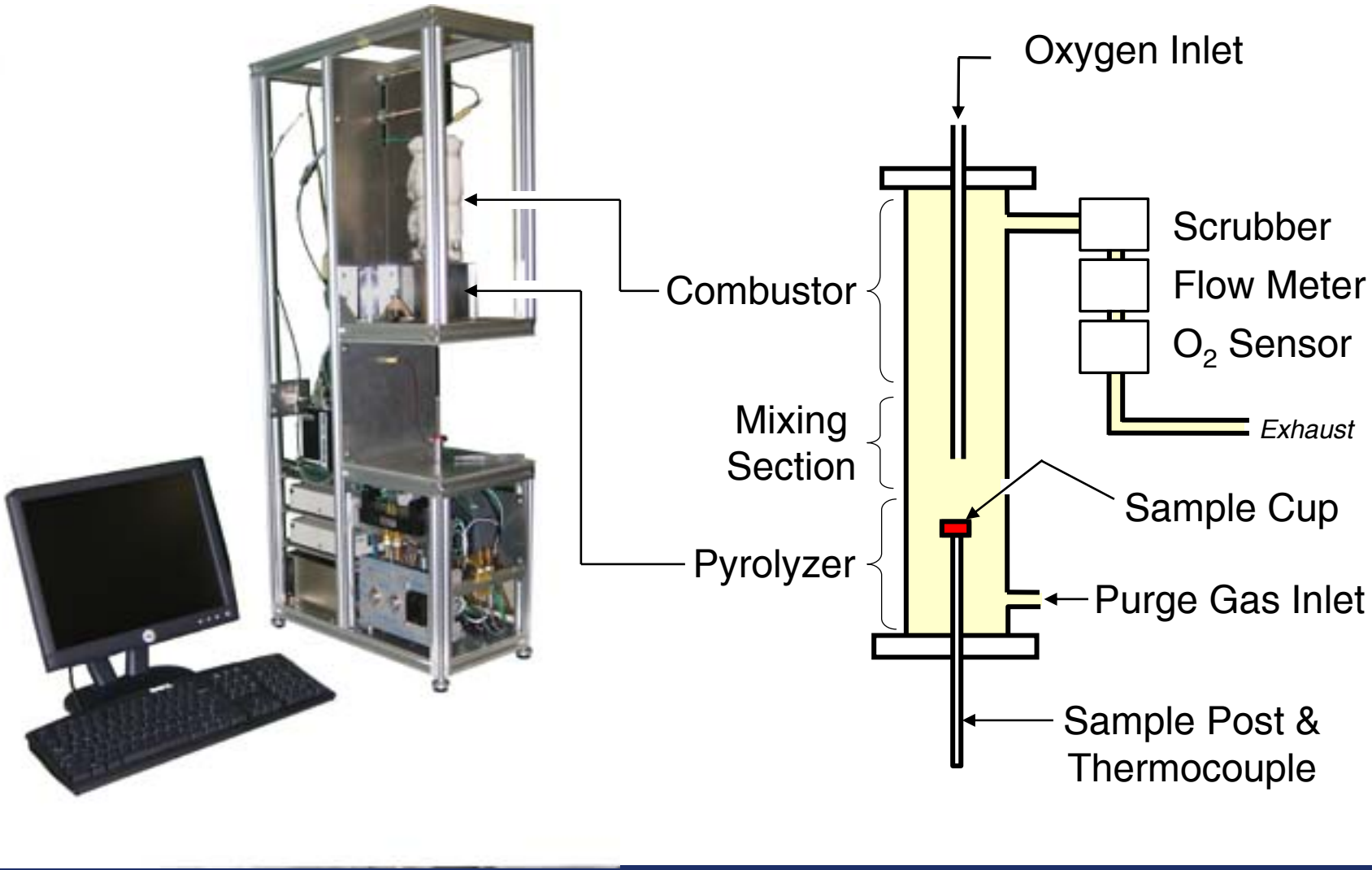
5 X 0.5 x 0.5 inches



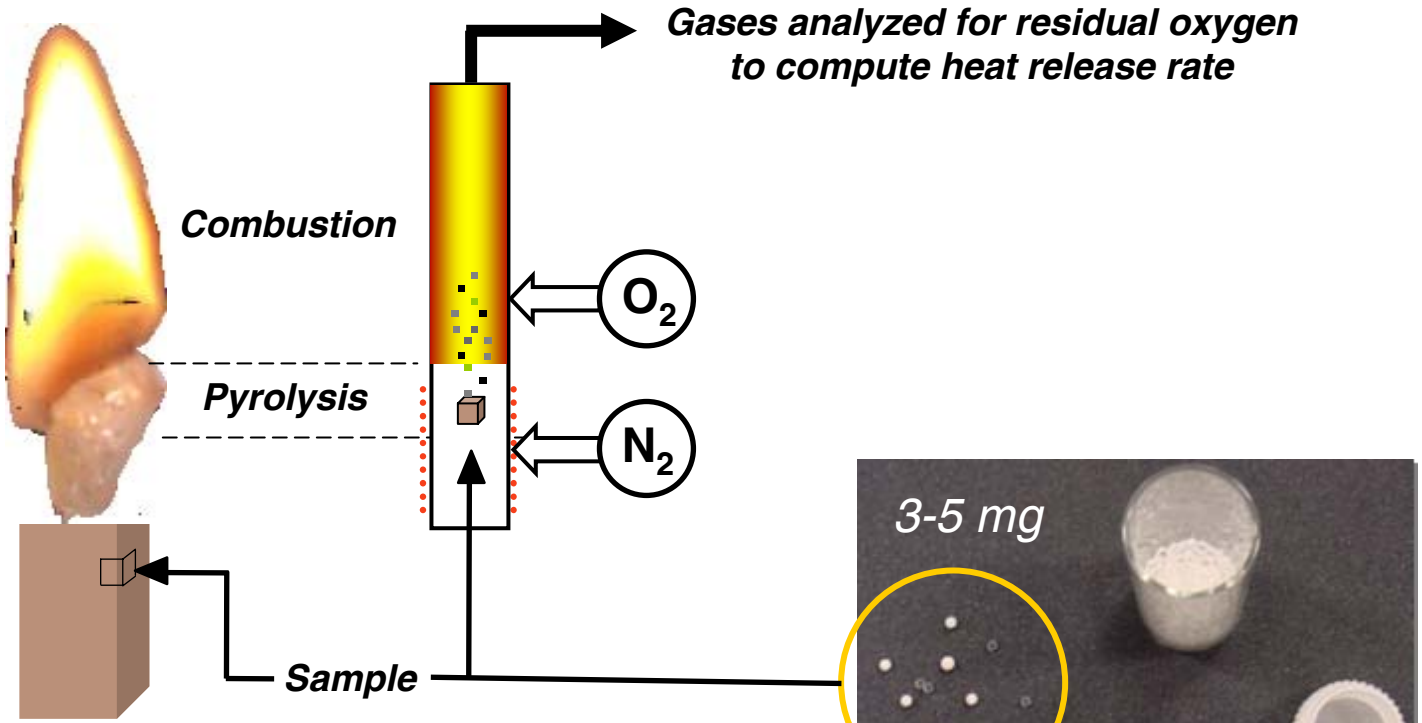


…Other?

FAA Microscale Combustion Calorimeter ASTM D 7309



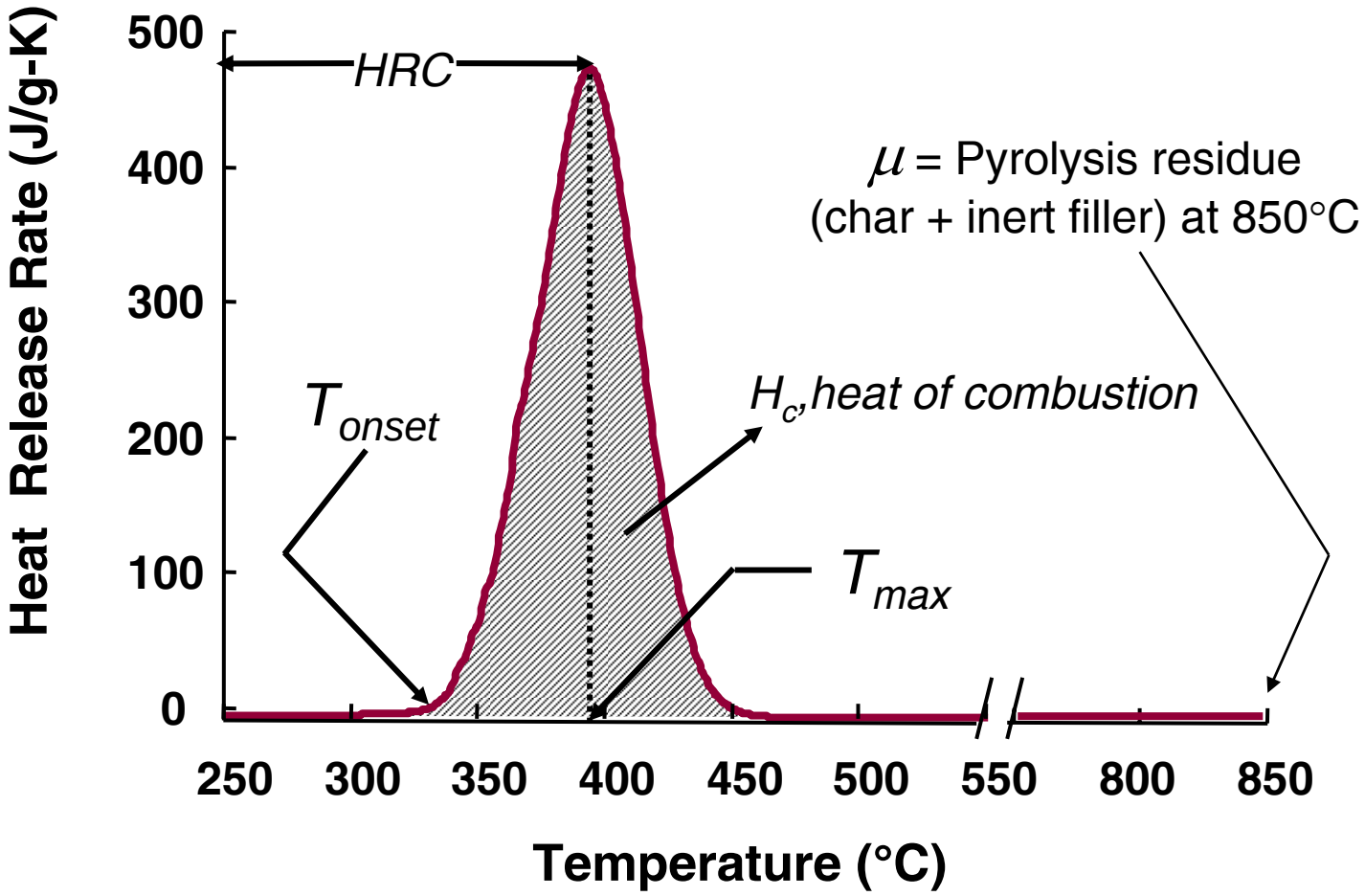
MCC Reproduces Elements of Flaming Combustion in Controlled Test



Flaming Combustion

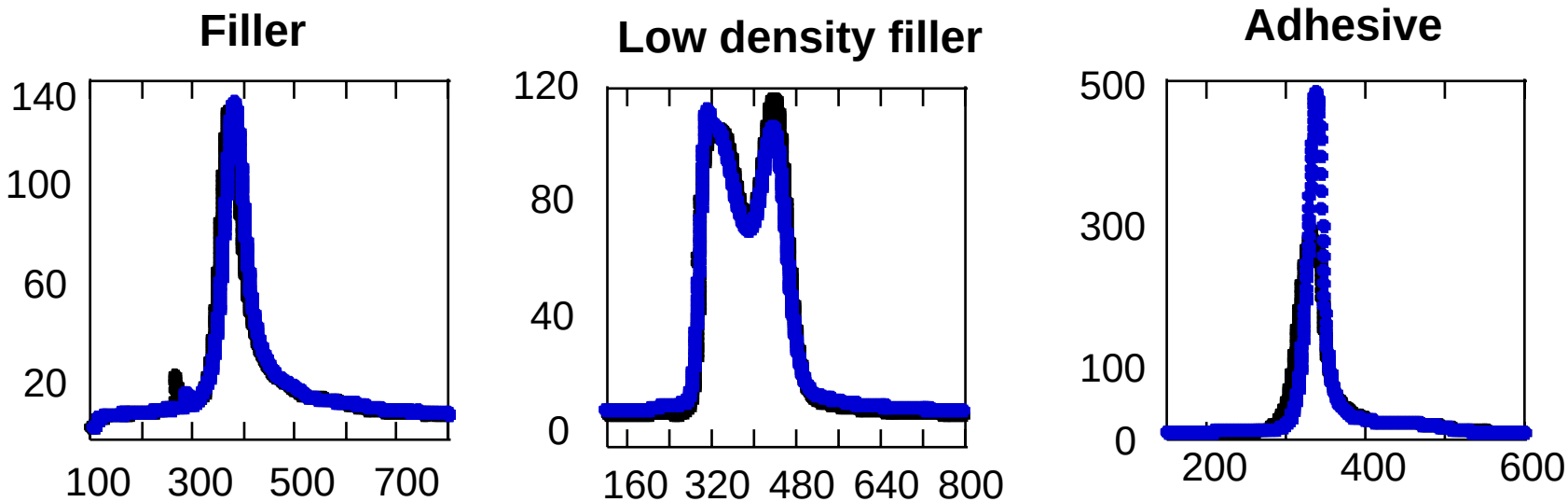
Microscale Combustion

5 Thermal Combustion Properties Measured in MCC Test



N	ADHESIVE APPLICATION	12s VBB	60s VBB	T_{onset} C	T_{max} C	HR kJ/g	H_c kJ/g_{gss}	HRC J/g-K	R	Char %
1	Low density filler	P	P	313	375	9	12.8	135	44	30
2	5 min epoxy	P	P	307	348	10.3	14.7	335	52	30
3	10 min epoxy	P	P	303	347	10.5	14.8	263	53	29
4	Adhesive	P	P	355	400	13.6	22.7	195	68	40
5	Epoxy Adhesive	P	P	300	336	12.5	18.9	235	69	34
6	Adhesive	P	P	300	337	14.2	19.8	490	72	29
7	Adhesive bonding	P	P	280	327	13.8	20	295	78	31
8	Adhesive	P	P	280	335	14.1	20.1	365	79	30
9	Epoxy Core Fill	P	P	311	375	17.6	23.5	220	80	25
10	Epoxy Core Fill	P	P	285	340	13.3	21.1	285	81	37
11	Edge fill	P	P	270	300	15.8	20.8	228	84	24
12	Epoxy Insert Adhesive	P	F	300	345	16.4	23.8	245	86	31
13	Epoxy Adhesive	P	F	325	345	19.8	26.1	335	87	24
14	Low density filler	P	P	285	364	16.2	23.1	205	88	30
15	Edge fill	P	P	280	445	16.4	23.4	185	88	30
16	Edge fill, adhesive	P	P	313	382	7	10	80	88	30
17	Insert adhesive	F	F	320	379	21.2	26.2	320	88	19
18	Panel inert adhesive	F	F	340	390	25.0	28.1	395	89	11
19	Low density filler	F	F	280	313	16.2	23.1	181	91	30
20	Adhesive	P	F	285	342	20	24.1	280	92	17
21	Edge fill	F	F	275	311	18.0	23.1	310	92	22
22	Adhesive	F	F	325	378	25.9	27.8	425	93	7
23	Adhesive	F	F	315	379	26.0	28.2	370	97	8
24	Epoxy Edge Fill	P	P	235	311	13.8	20.6	200	98	33
25	Panel & Insert adhesive	F	F	300	394	22	28.9	200	101	24

Reproducibility of HRR for Samples from Different Sources Is Excellent



Same Sample has Pass & Fail VBB rating

Heat Release Rate (HRR) of Combustible Solids

$$HRR = \frac{H_c}{H_g}(q''_{ext} + q''_{flame} - q''_{rerad})$$

q''_{rerad} — Surface heat loss by reradiation

q''_{flame} — Heat flux from attached flame

q''_{ext} — External heat flux

H_c — Heat of combustion of fuel gases

H_g — Heat required to generate fuel gases

$H_c = HR/(1-\mu)$

μ = Pyrolysis residue (g/g)

Flame Spread Criterion for Combustible Solids

- *Assume critical heat release for flame spread (burning), HRR* ≈ 200 kW/m² in radiant panel test.*
  - *Assume heat required to generate gaseous fuel from solid is*

$$H_g = C\,(T_{onset} - T_0) + h_{vaporization}$$
$$\approx 2C\,(T_{onset} - T_0)$$

T_{onset} = thermal degradation temp.

T_0 = room temp.

C = heat capacity

  - *Condition for flame spread is:*

$$\frac{H_c}{T_{onset} - T_0} \geq \frac{2C\,HRR^*}{(q''_{ext} + q''_{flame} - q''_{rerad})}$$

Quantifying MCC Properties as Predictors of Pass/Fail VBB Results

N_{pass} = Number of passing results

N_{fail} = Number of failing results

$N = N_{pass} + N_{fail} = 25$

N_{FP} = Number of False Positives

= Number failing results within range of passing results for ranked data

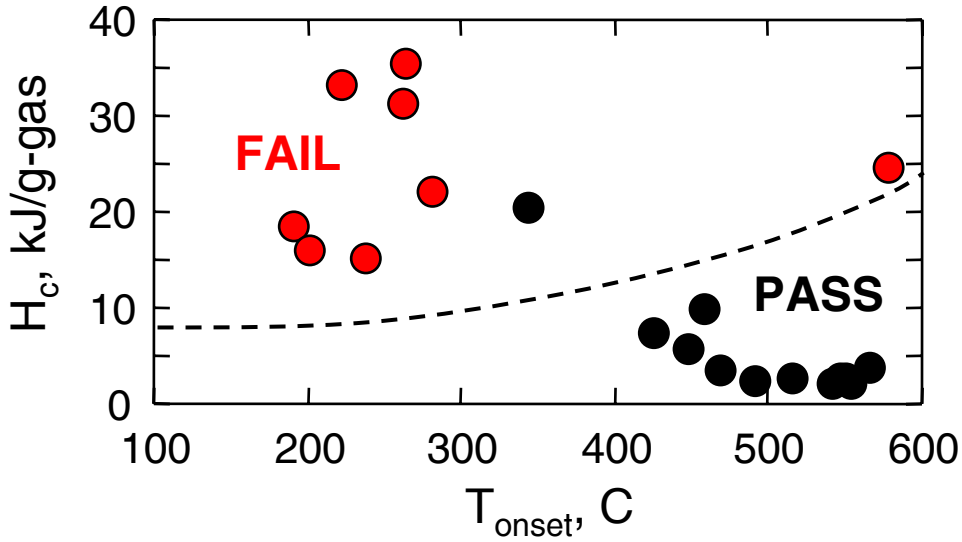
$$\text{False Positive Rate (\%)} = \frac{N_{FP}}{N - N_{FP}} \times 100$$

MCC Criteria for Radiant Panel Test of A/C Electrical Wires

Flame Spread Criterion (2-D)

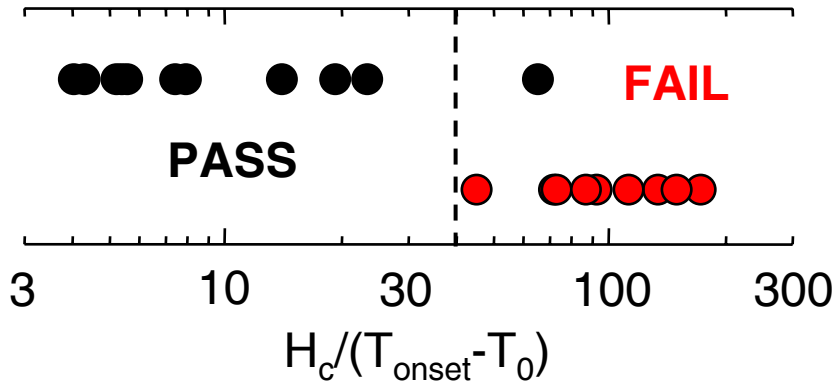
(J. Reinhardt, FAA, FTWG, 2009)

5% False Positives

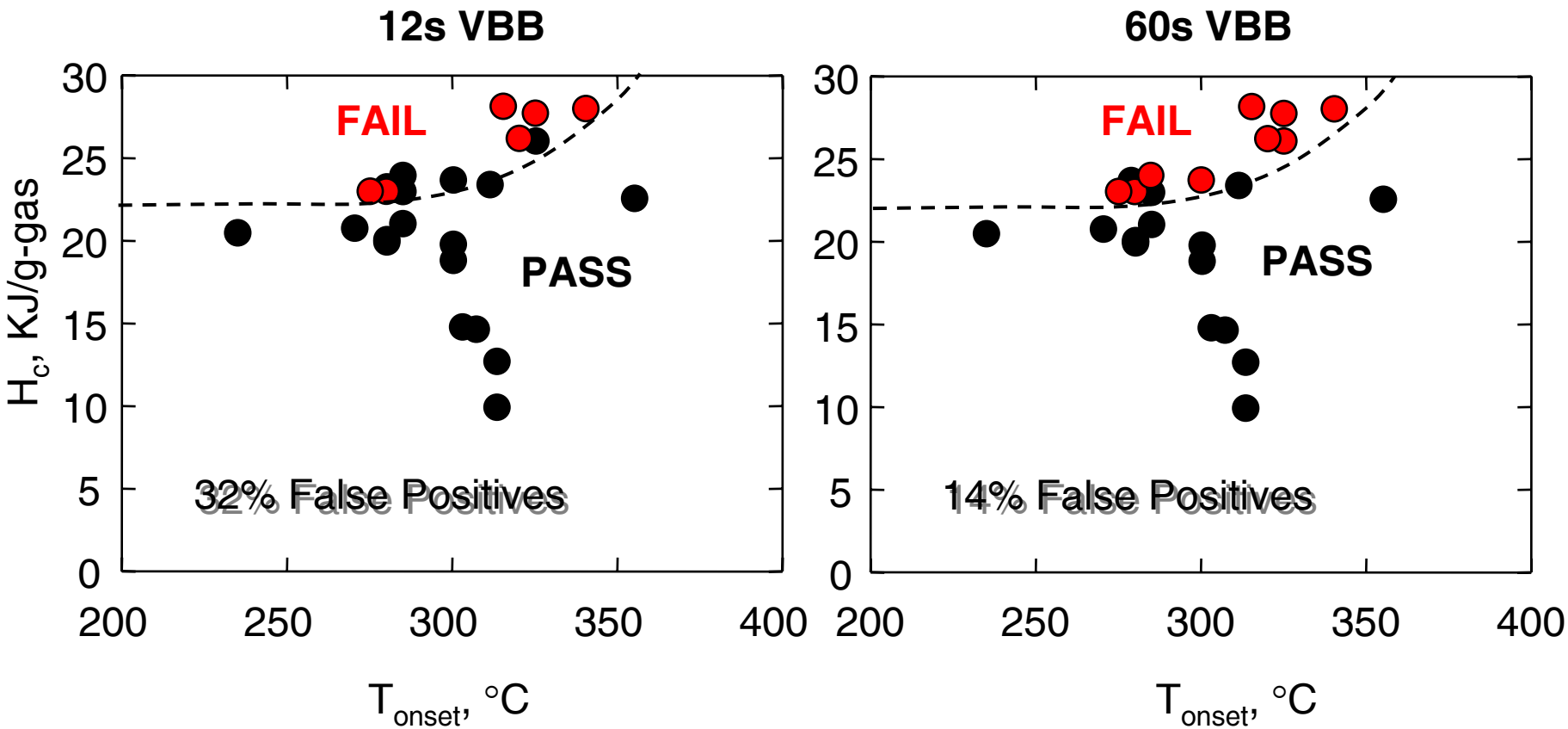


Flame Spread Criterion (1-D)

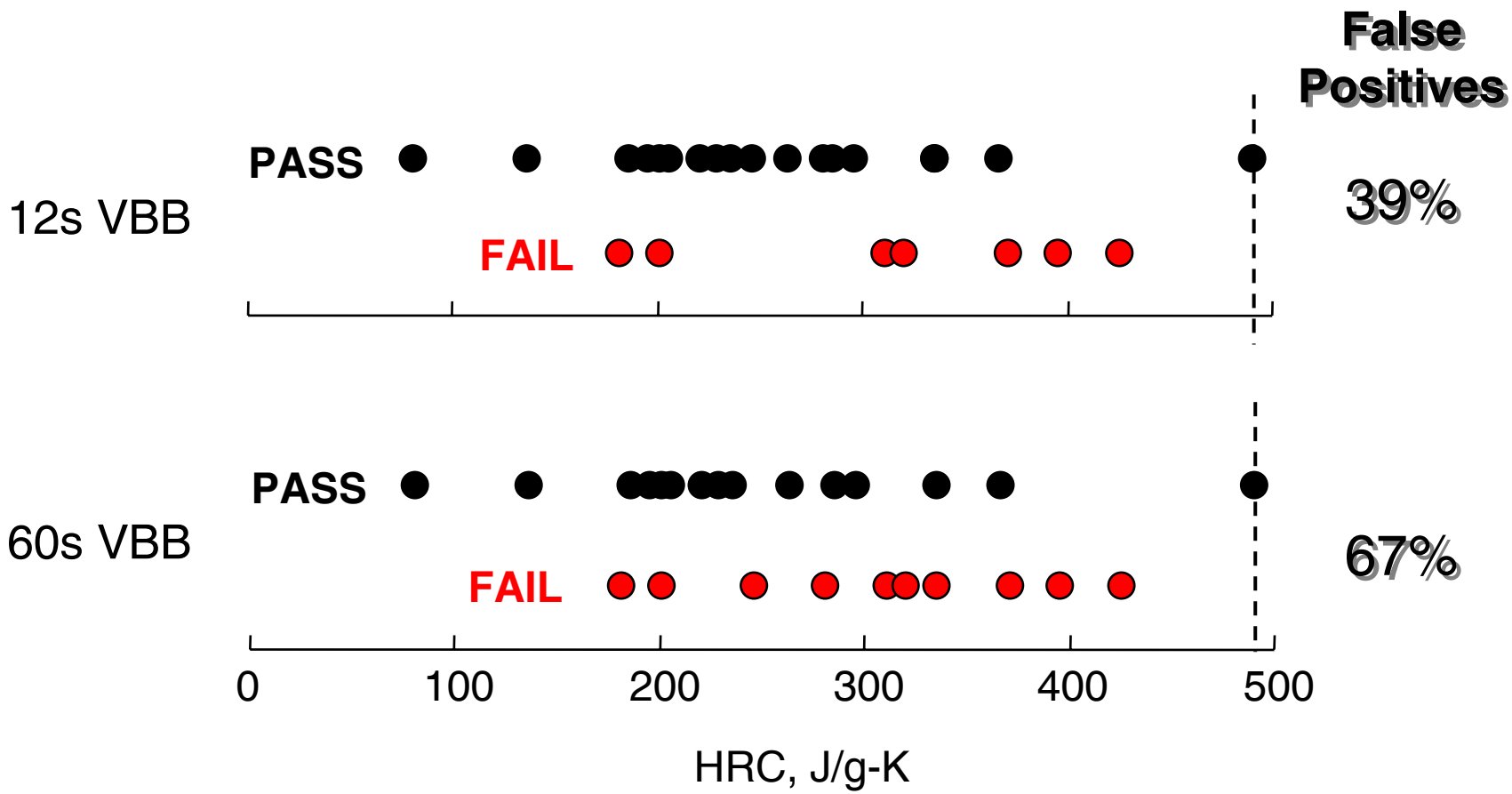
5% False Positives



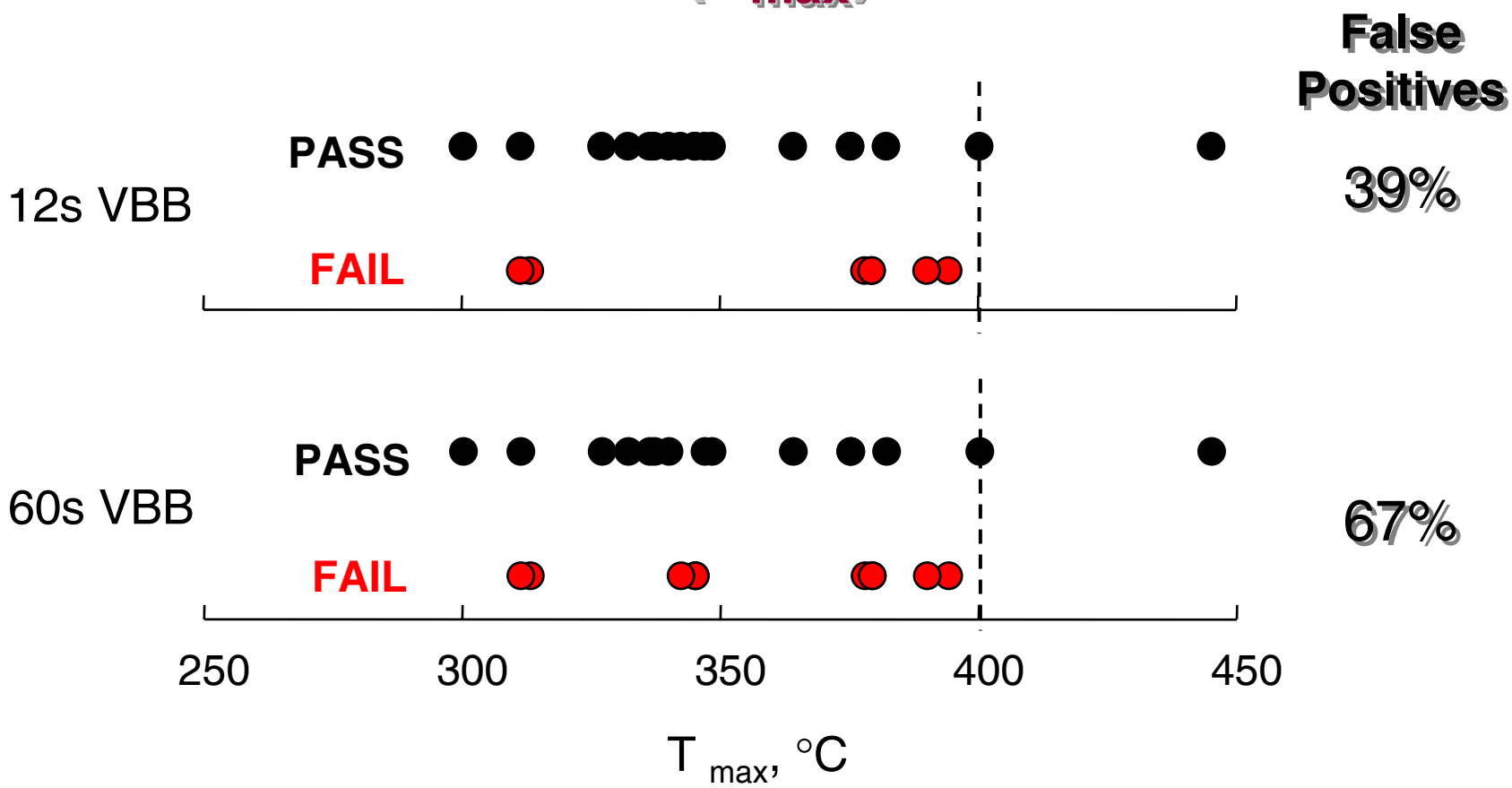
2-D Criterion Not as Good for VBB of Adhesives



VBB versus Heat Release Capacity

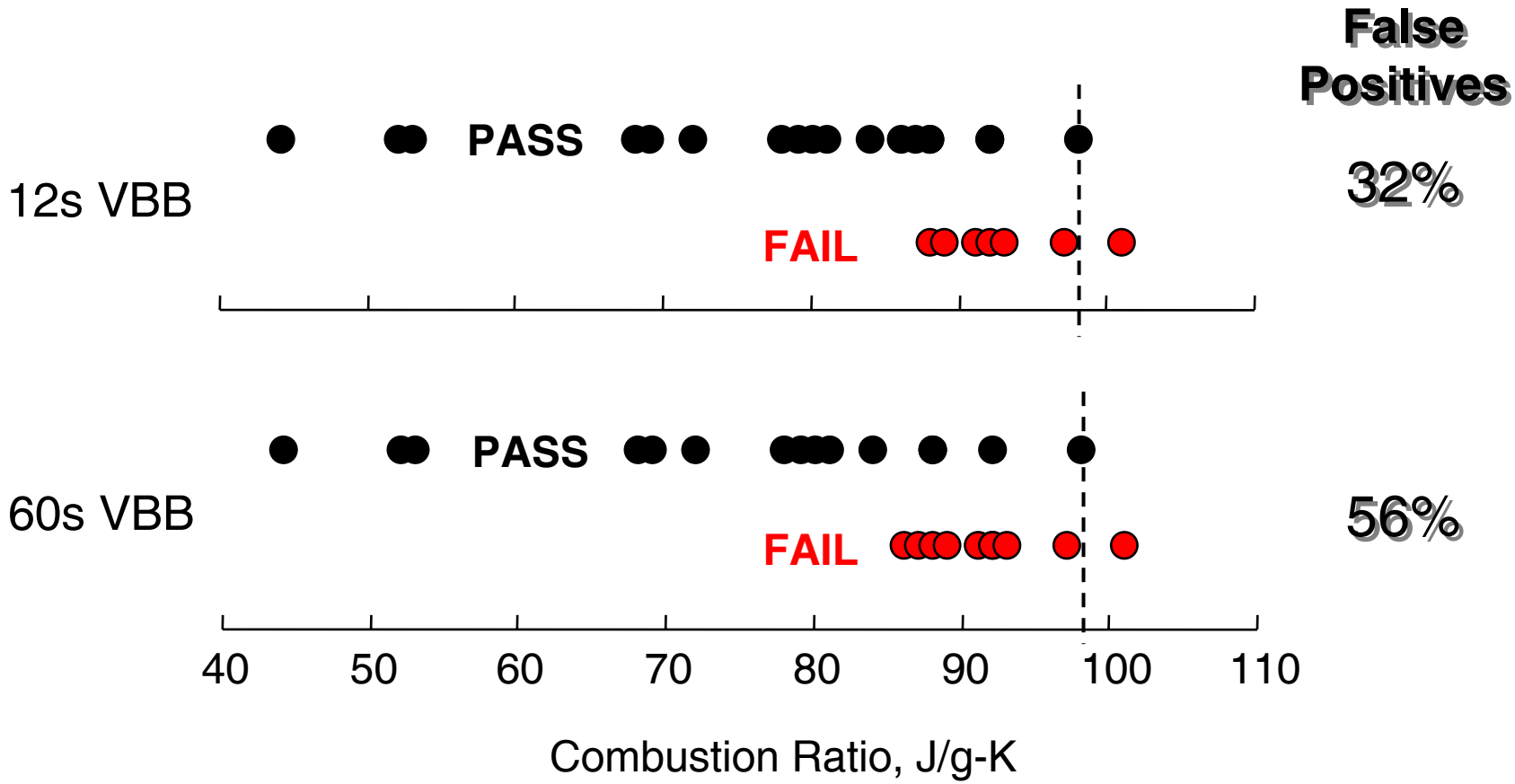


VBB versus Temperature at Max HRR (T_{max})

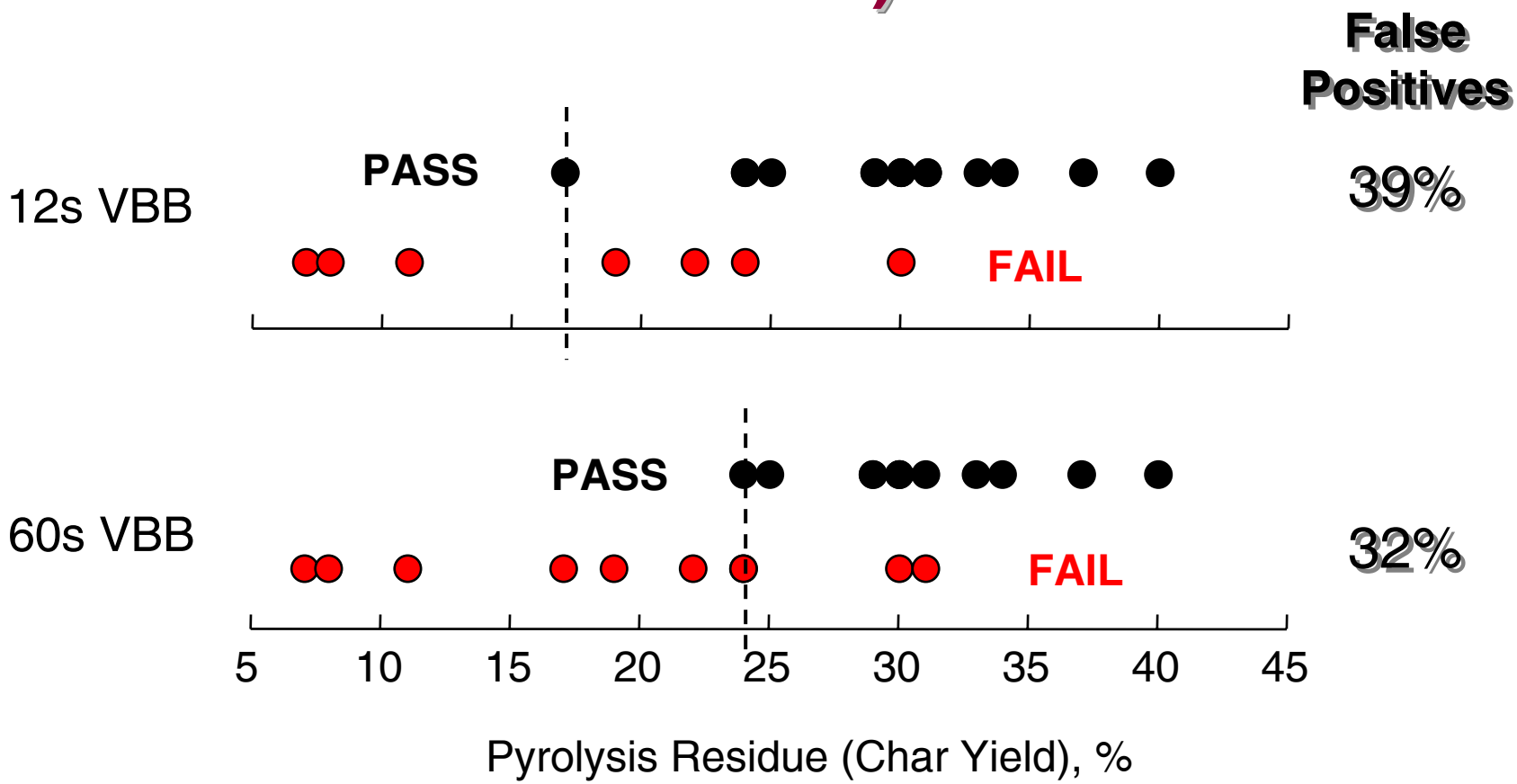


VBB versus Combustion Ratio, R

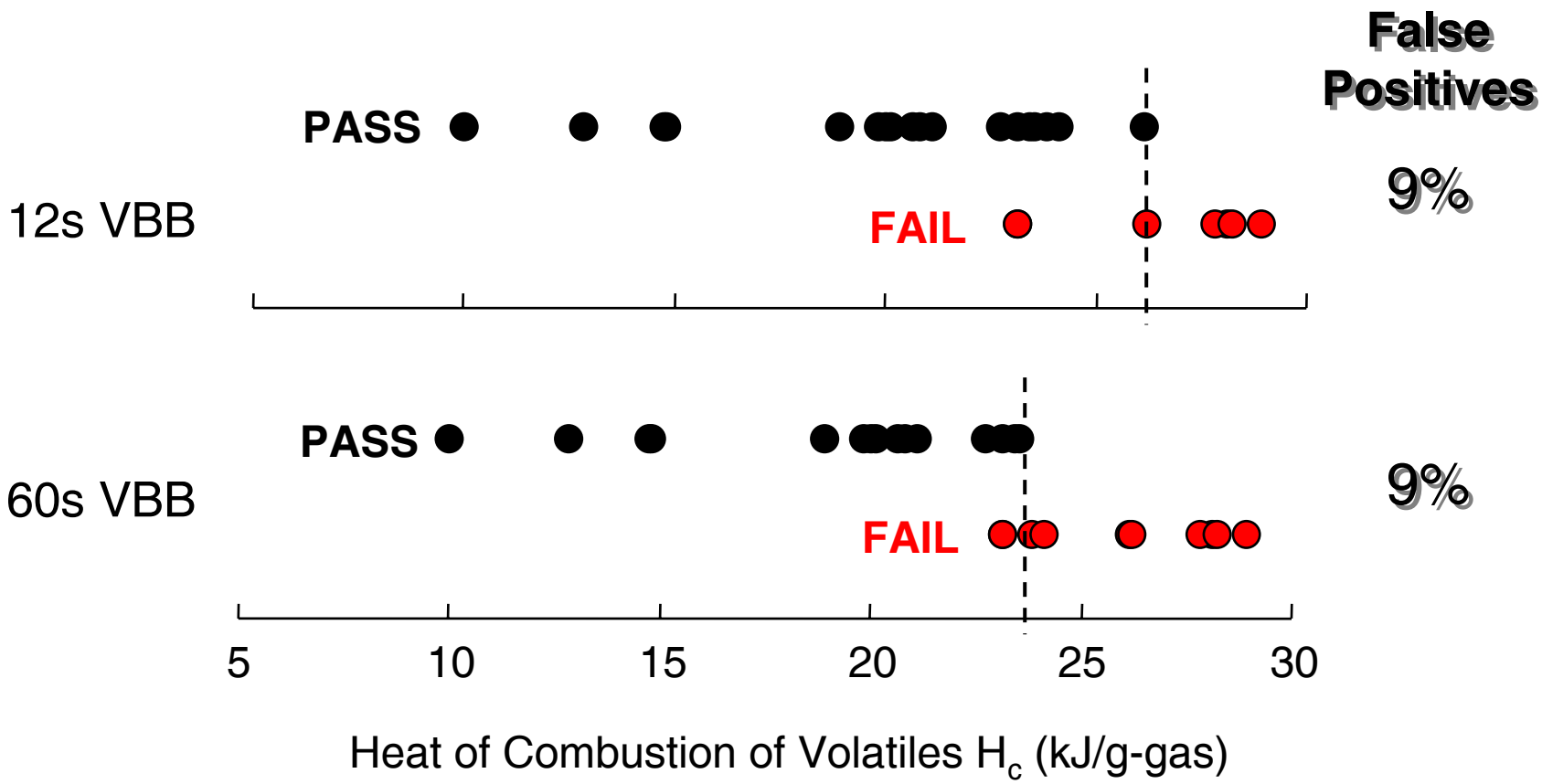
$$R = H_c/(T_{onset} - T_0)$$



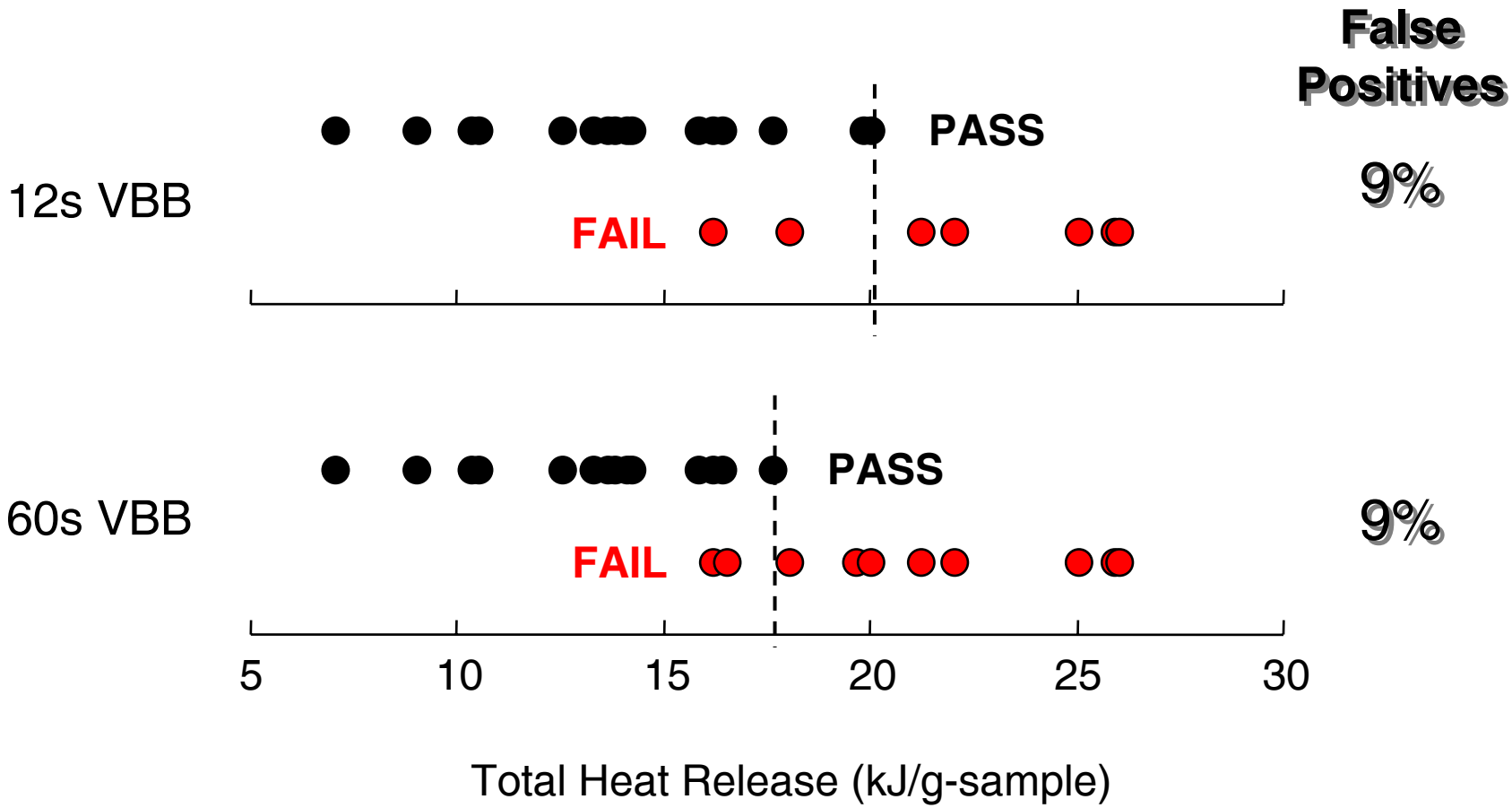
VBB versus Pyrolysis Residue (Char Yield)



VBB versus Heat of Combustion of Volatiles, H_c



VBB versus Total Heat Release



Conclusions

- Microscale Combustion Calorimeter properties that are highly correlated (< 10% false positive) with 12s and 60s VBB results are:
  - Total Heat Release of Sample (HR)
  - Heat of Combustion of Fuel Gases (H_c)

  More conservative choice of HR or H_c will eliminate false positives.

- A limited number of samples (25 total, 22 different) were tested in this study.

- Sample size was not controlled in the VBB test and is a source of variability in the P/F results.