Heat Release Rate in Cargo Fires

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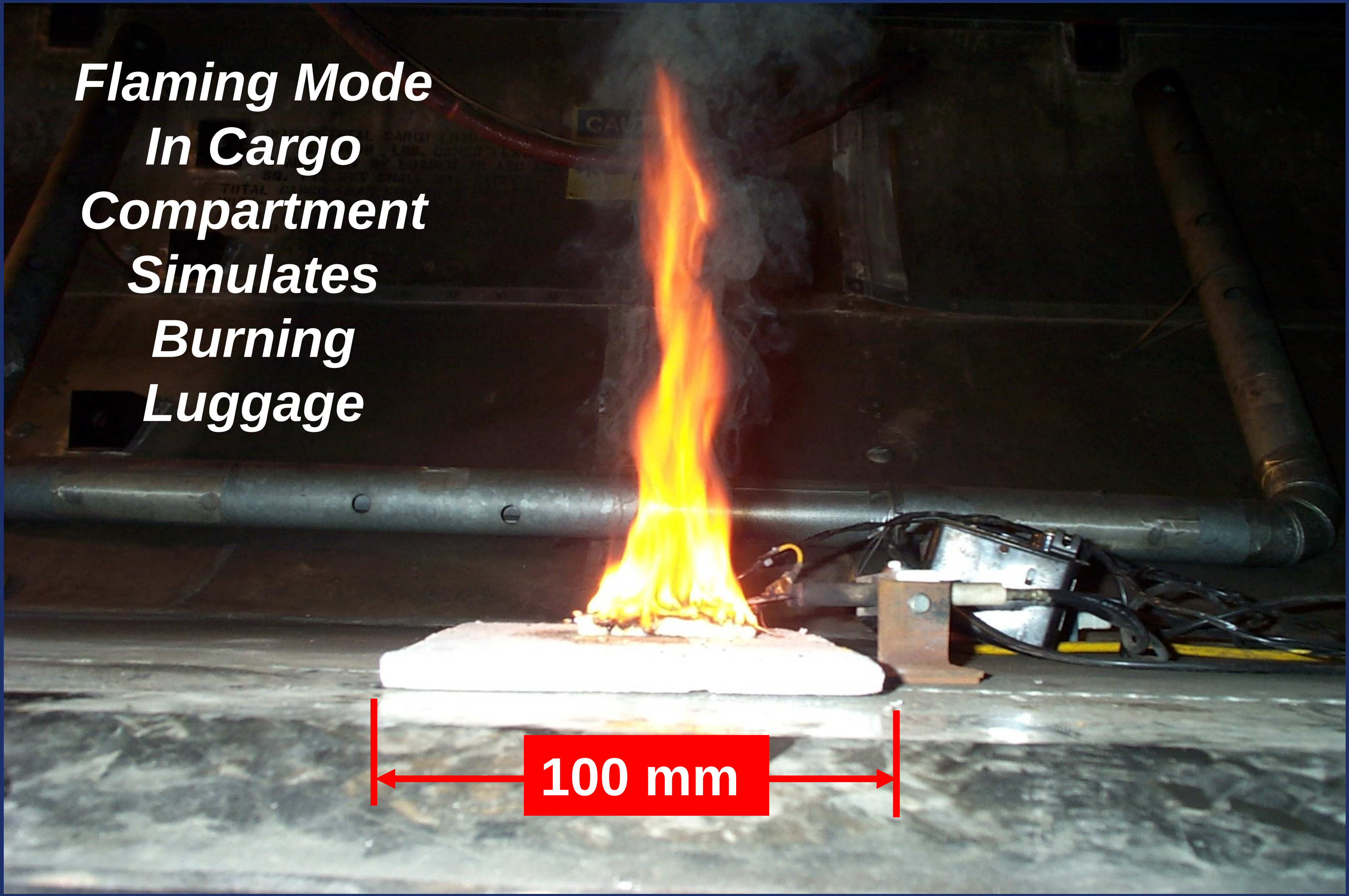
OBJECTIVE

Measure release rate of combustion products from object(s) burning in a ventilated cargo compartment.

Use data as source term in CFD modeling of smoke movement in cargo compartment.

MIXED PLASTIC SMOKE GENERATION SOURCE



APPROACH

Use perfect mixing model to relate exhaust gas concentration to combustion product release rate in (cargo) compartments.

EXPERIMENTAL

Generate known combustion product histories with a *premixed propane-air burner*.

Apply a *perfect mixing model* to exhaust gases drawn from cargo compartment.

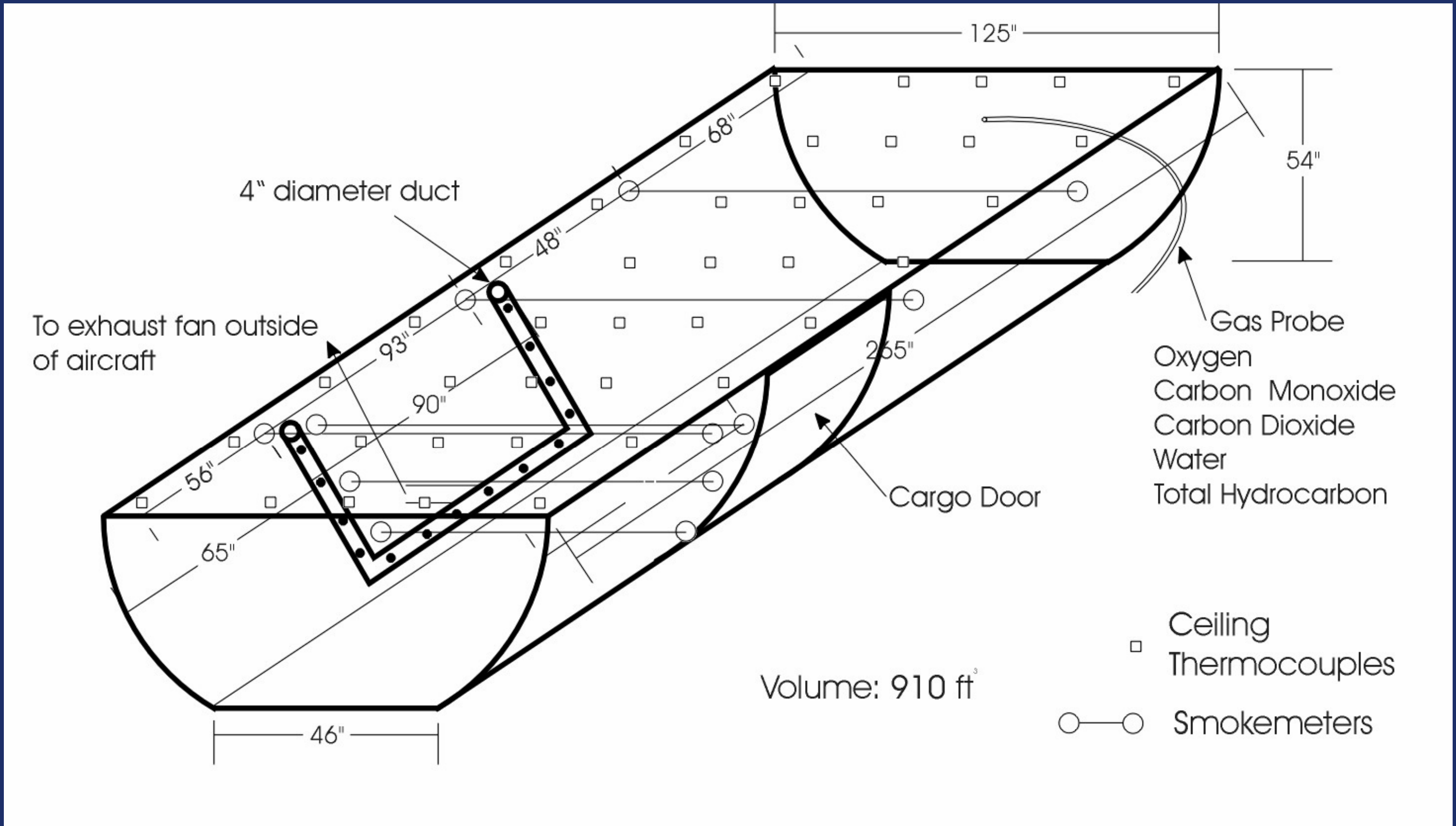
Compare mixing model to:

- *oxygen consumption* (heat release rate) history.
- *temperature history*.

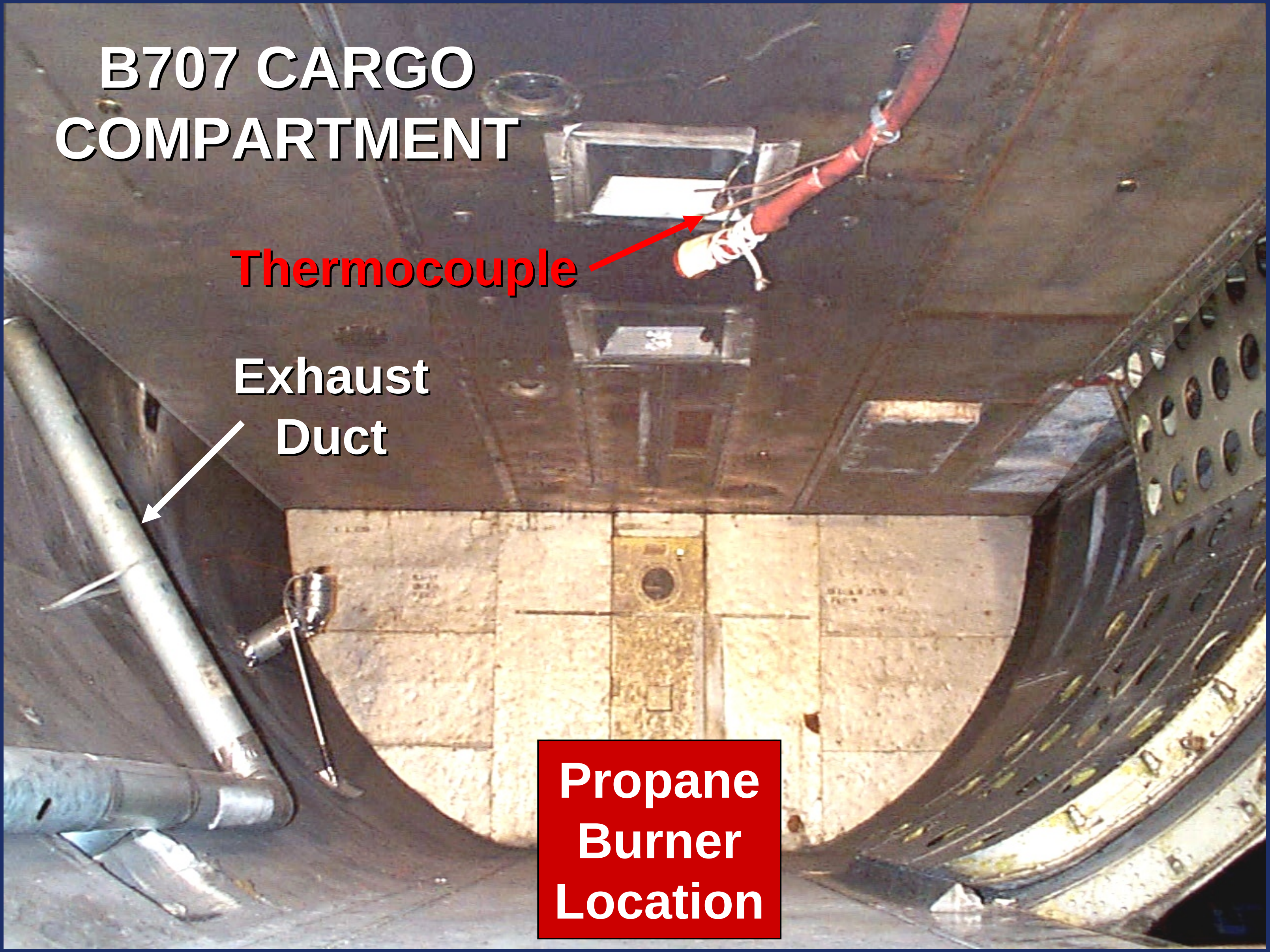
PROCEDURE

- Position premixed propane-air burner at center of B707 cargo compartment.
- Attach thermocouple to ceiling directly above burner.
- Measure exhaust gas flow rate (F) and $[O_2]$.
- Calculate HRR from F, $\Delta[O_2]$ using spread-sheet mixing model.
- Test effects of forced circulation on results.

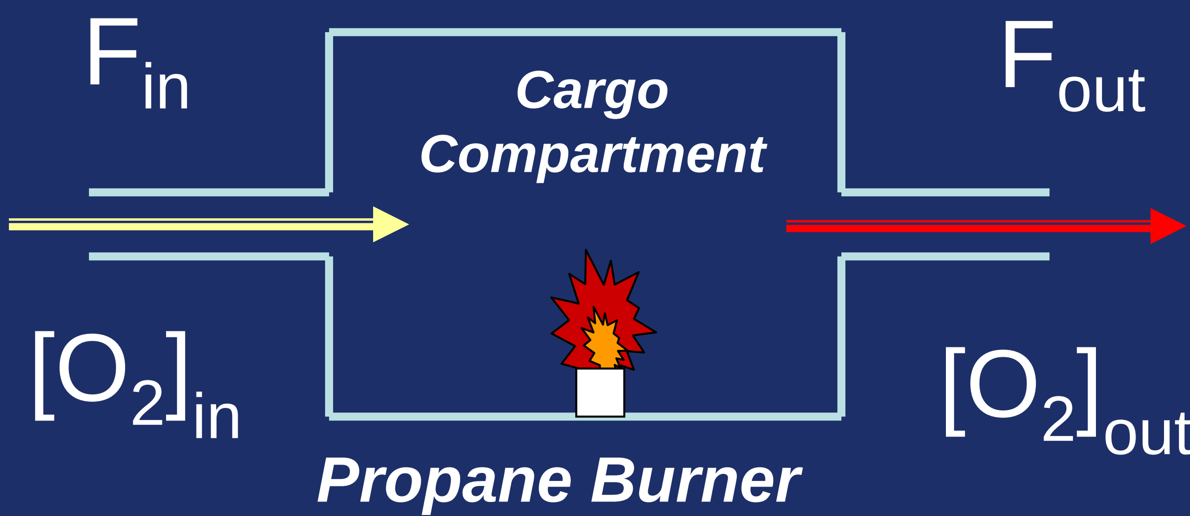
TEST CONFIGURATION



707 Forward Cargo Compartment


B707 CARGO COMPARTMENT
Thermocouple
Exhaust Duct
Propane Burner Location

PERFECT MIXING MODEL



MASS BALANCE: $\rho F_{in} = \rho F_{out} = \rho F$

SPECIES BALANCE: $[O_2]_{in} - [O_2]_{out} = \Delta[O_2] = \theta$

MIXING MODEL SOLUTION FOR HRR

$$\mathrm{HRR}(t) = \rho FE \left\{ \theta + \tau \frac{d\theta}{dt} \right\}$$

$$\tau = \frac{\text{Compartment Volume (m}^3)}{\text{Flow Rate (m}^3/\text{s)}}$$

TEST PARAMETERS

Cargo compartment volume = 26 m^3

Exhaust flow rate, F = 0.018 m^3/s

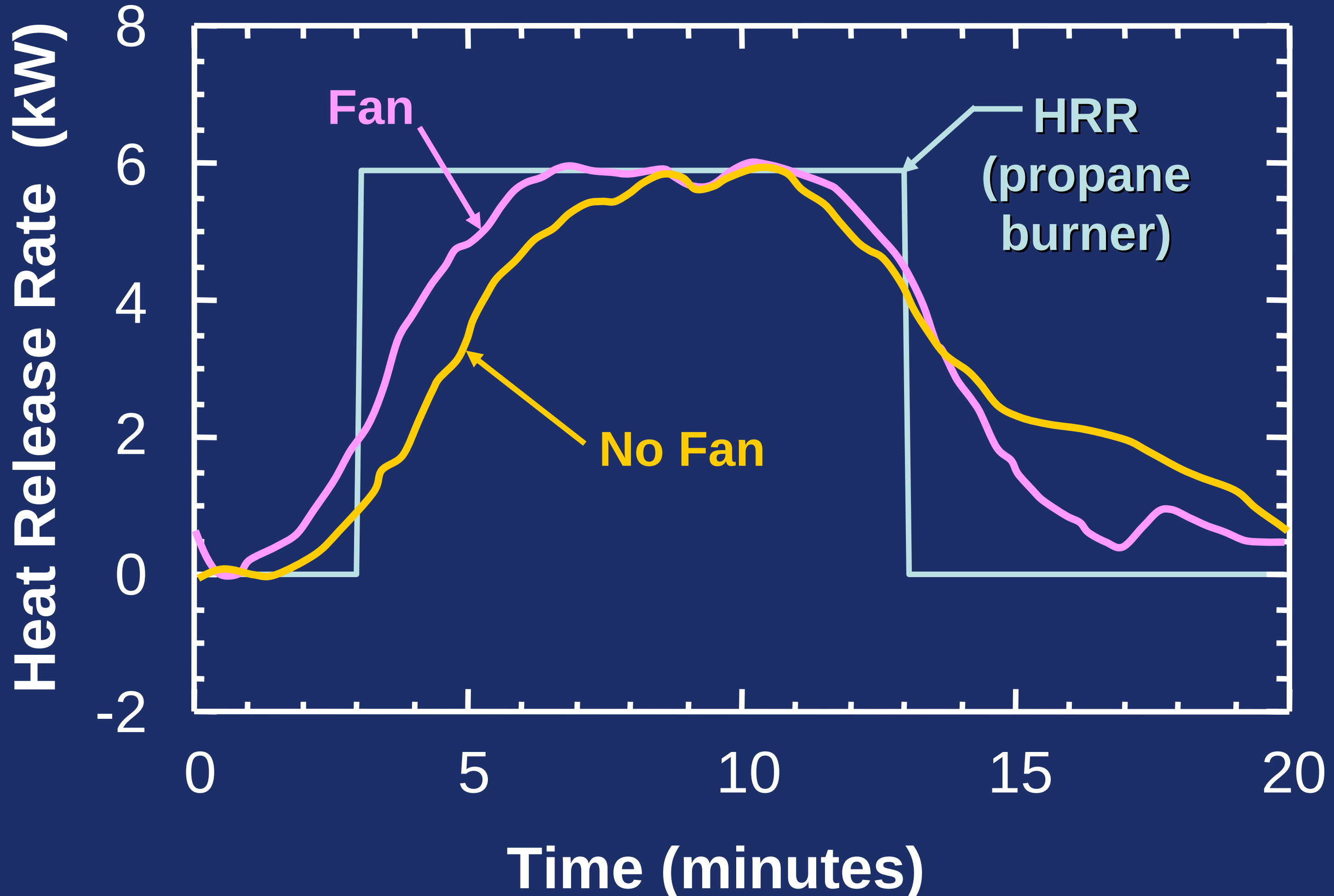
Heat of combustion of oxygen,
E = 12.78 MJ/kg-O_2 (propane)

Ambient temperature, T = 27 °C (81 °F)

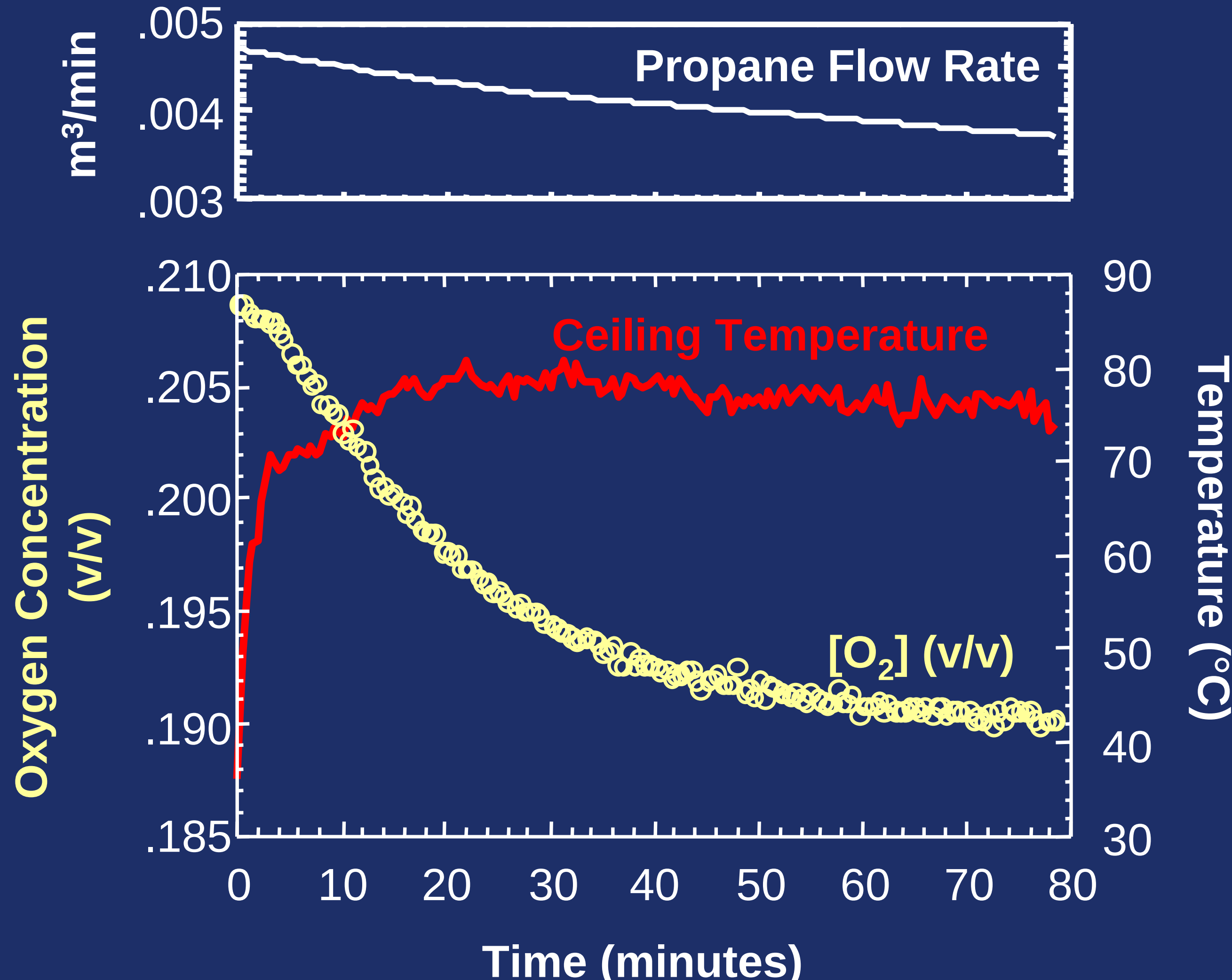
Air Density (27 °C), ρ = 1.2 kg/m^3

FORCED CIRCULATION

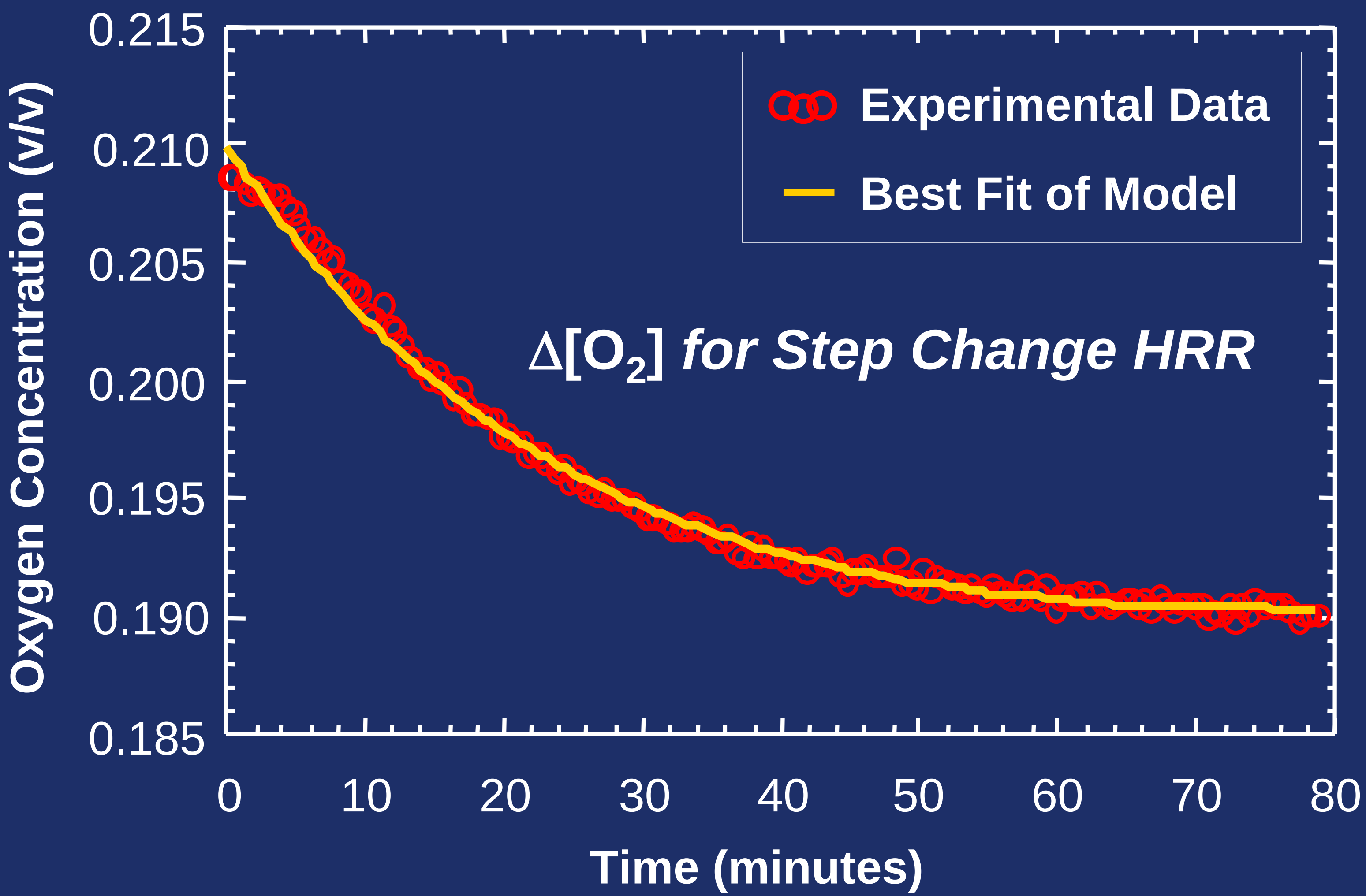
- Small improvement in fidelity
- But could spread flames



HRR STEP CHANGE



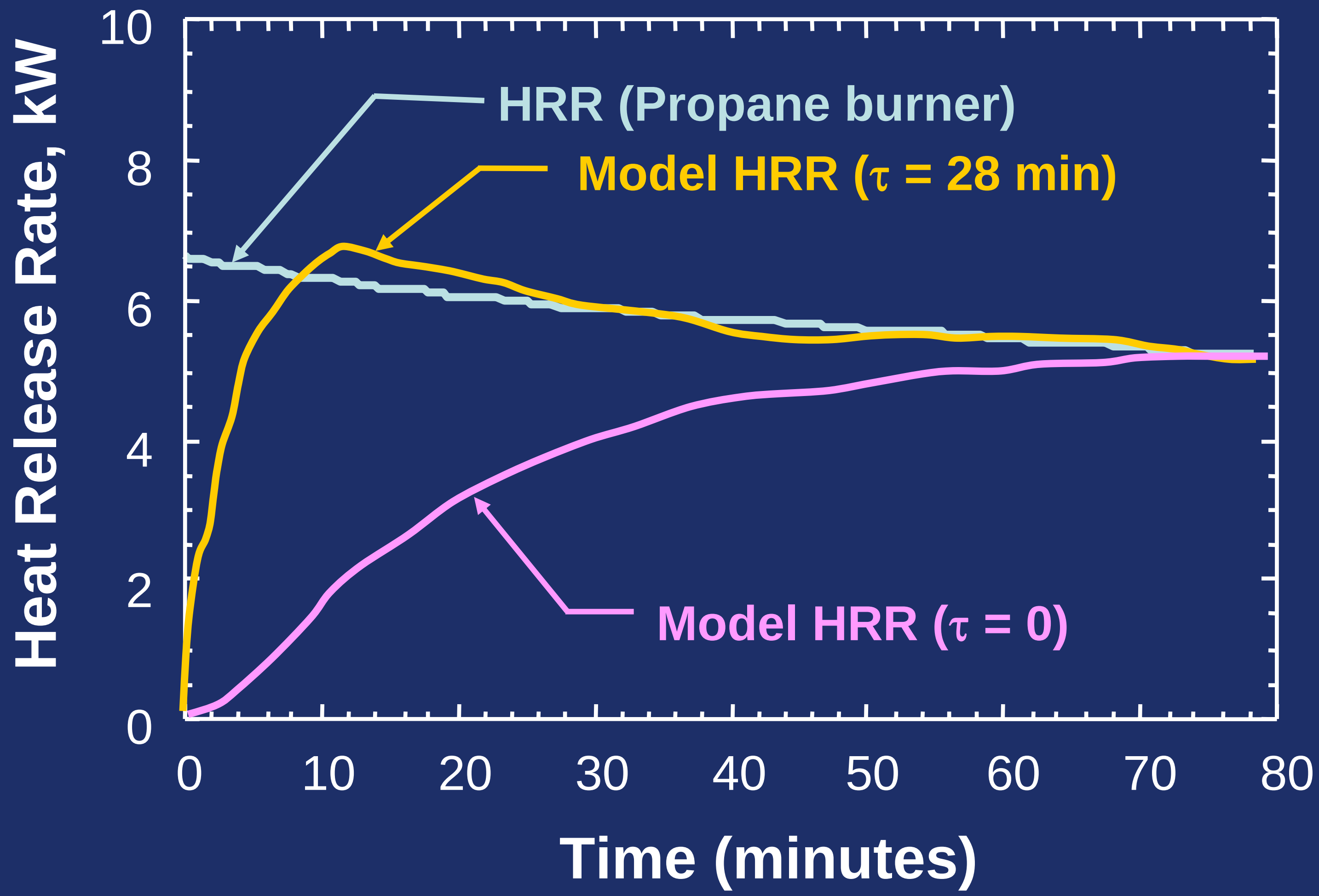
HRR MODEL CALIBRATION



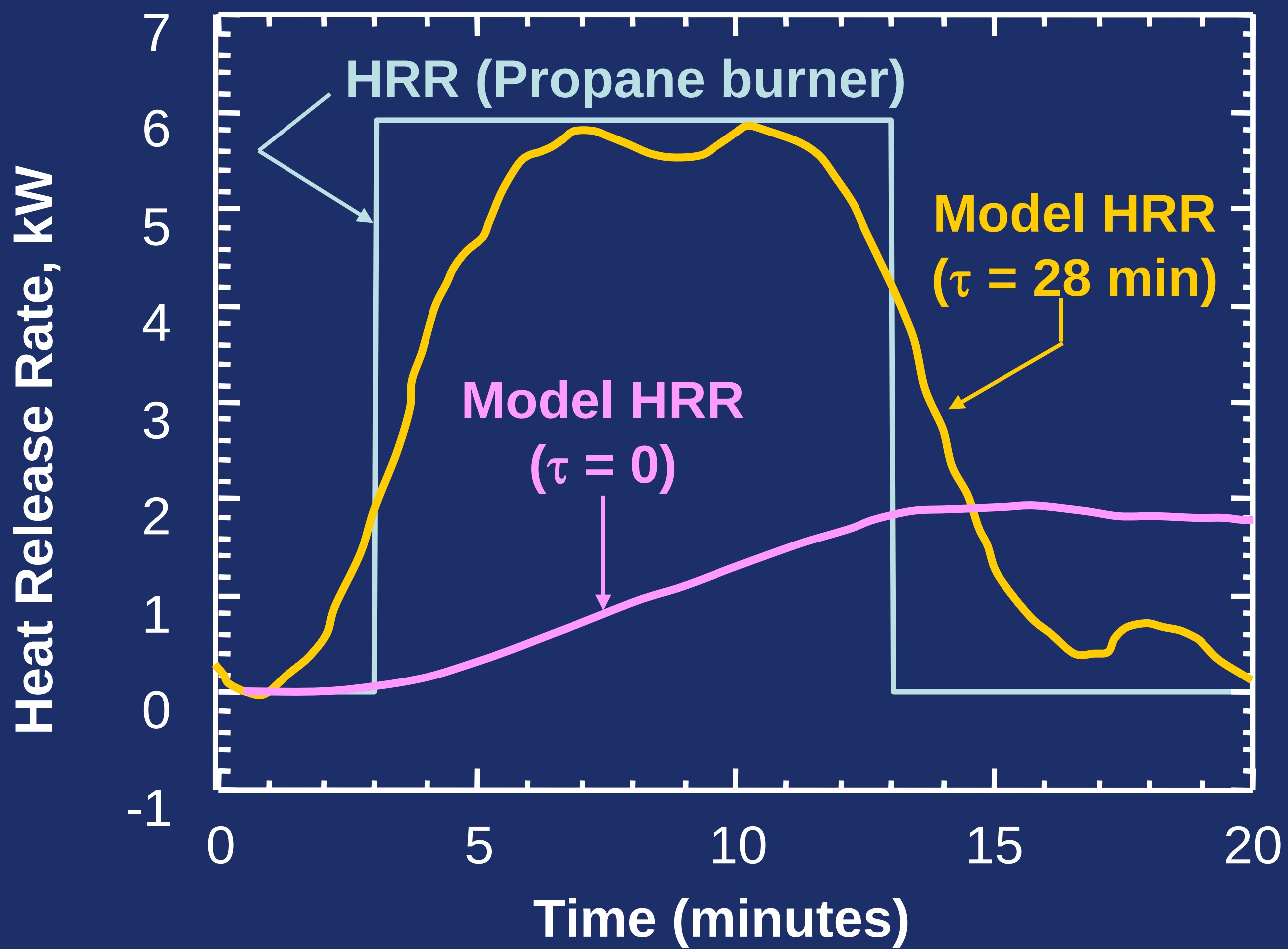
CALIBRATION RESULTS
(Propane Burner Step Change HRR)

Parameter	Calculated	Measured (Best Fit)
ρFE (kW)	276	270 ± 10
τ (min)	24	28

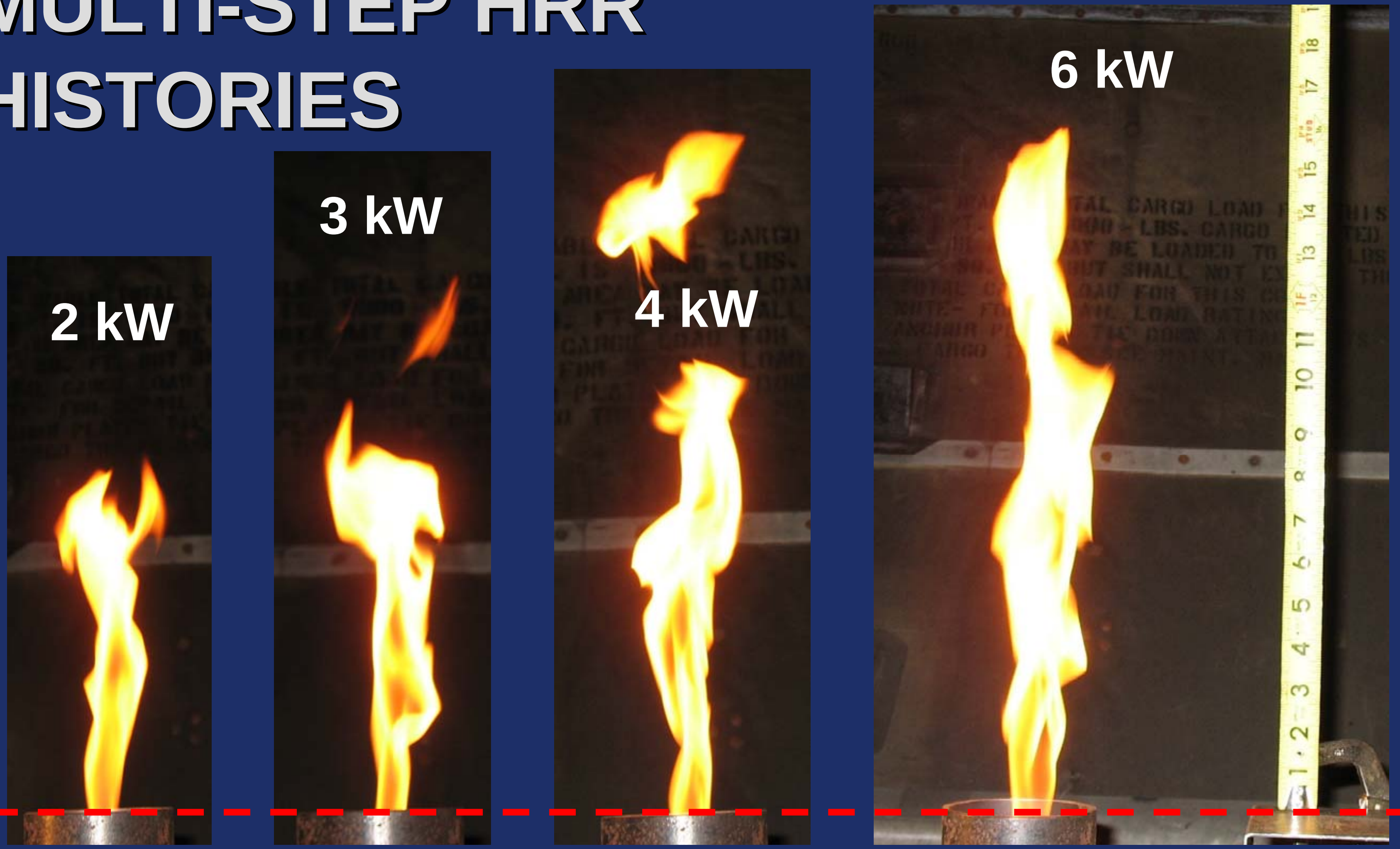
HRR STEP CHANGE



HRR SQUARE WAVE

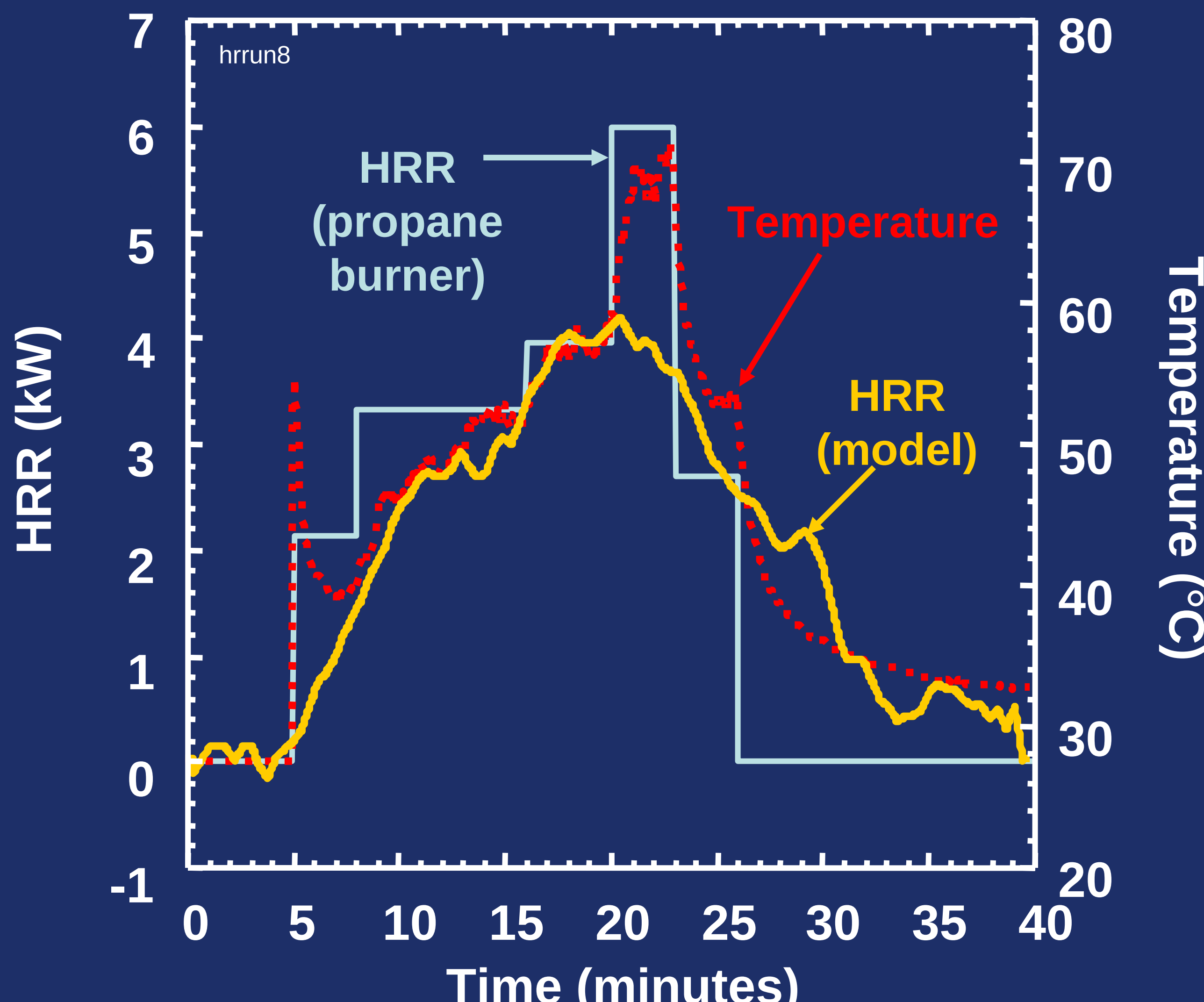


MULTI-STEP HRR HISTORIES

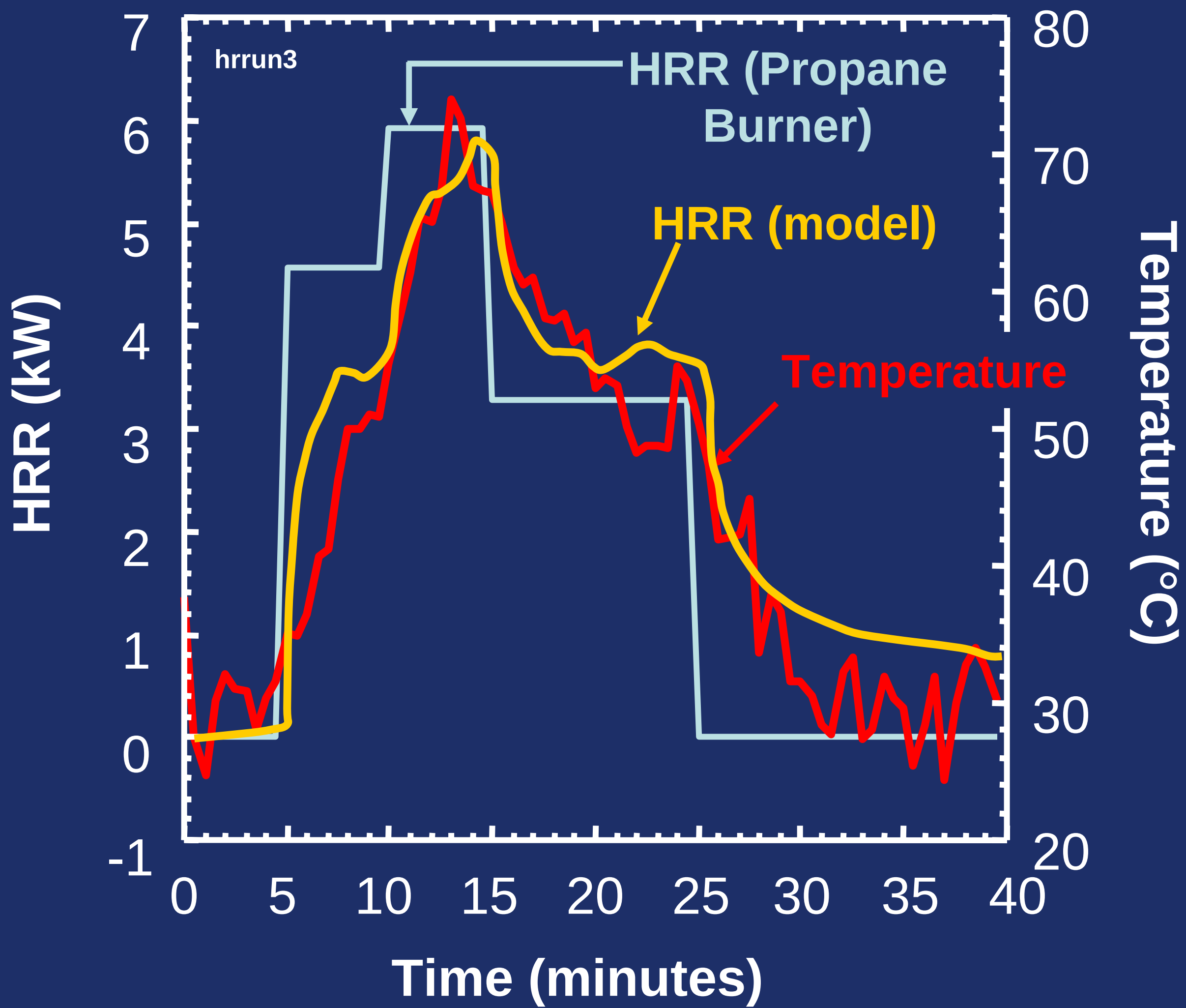


Propane Burner Flame Heights

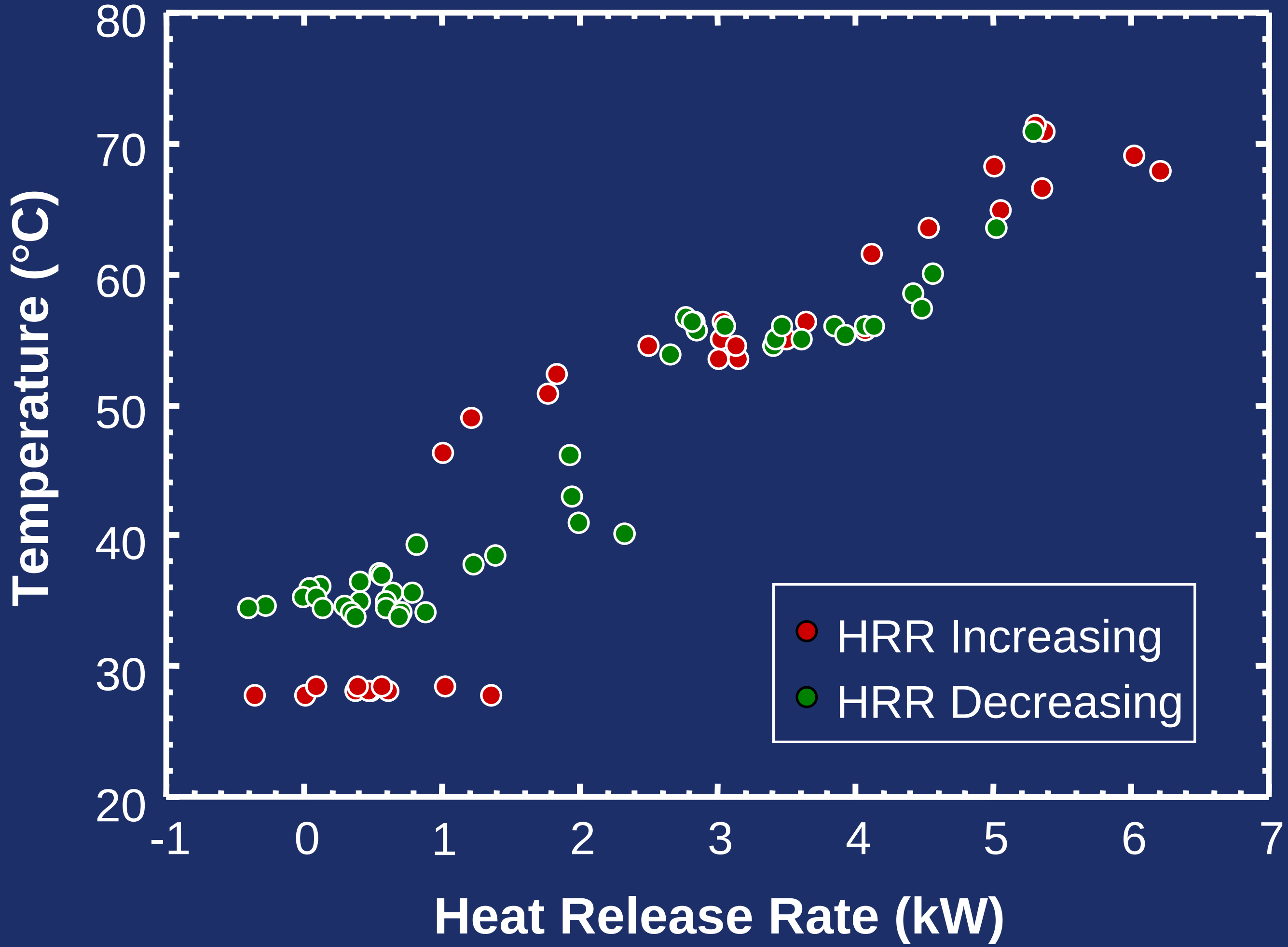
MULTI-STEP HRR 1



MULTI-STEP HRR 2



Temperature versus HRR for Multi-Step Histories



DISCUSSION

Mixing Model and Temperature Provide Comparable (R = 0.8) Resolution of Combustion Histories for Objects Burning in Compartments.

Advantage of Combustion Model is:

- Measures Heat Release Rate
- Easily Calibrated
- Independent of Size and Position of Burning Object(s) with good mixing.

CONCLUSIONS

Mixing Model Provides Reasonable Combustion Product Release Rates and Histories for Objects in Compartments When-

$$\text{Burning Time} \le \tau \approx \frac{\text{Compartment Volume}}{\text{Exhaust Flow Rate}}$$