EFFECTS OF VENTILATION ON MATERIAL PROPERTIES

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BUILDING FIRES

- One of the major objectives of the building fire research at NIST is to develop fire growth and spread model(s) to predict temperature and concentrations of smoke and toxic compounds in buildings;
- Ventilation is one of the most important factor governing fire growth and spread in buildings. It is, therefore, necessary to understand the ventilation-controlled fire behavior in buildings.

VENTILATION-CONTROLLED FIRES

- Ventilation-controlled fire behavior has been investigated in various studies using test set ups such as the “Hood”, “Enclosure”, “Reduced-Scale Enclosure, RSE, ISO 9705”, and the “Flammability Apparatus (ASTM E2058)”;
- The behavior has been defined in terms of correlations of product concentrations and material properties for well-ventilated and ventilation-controlled fires and the equivalence ratio;

VENTILATION-CONTROLLED FIRES

- The correlation is expressed as the Global Equivalence Ratio (GER) concept;
- Equivalence ratio:

$$\Phi = s_o \, \dot{m}_f / \dot{m}_o = s_a \dot{m}_f / \dot{m}_a$$

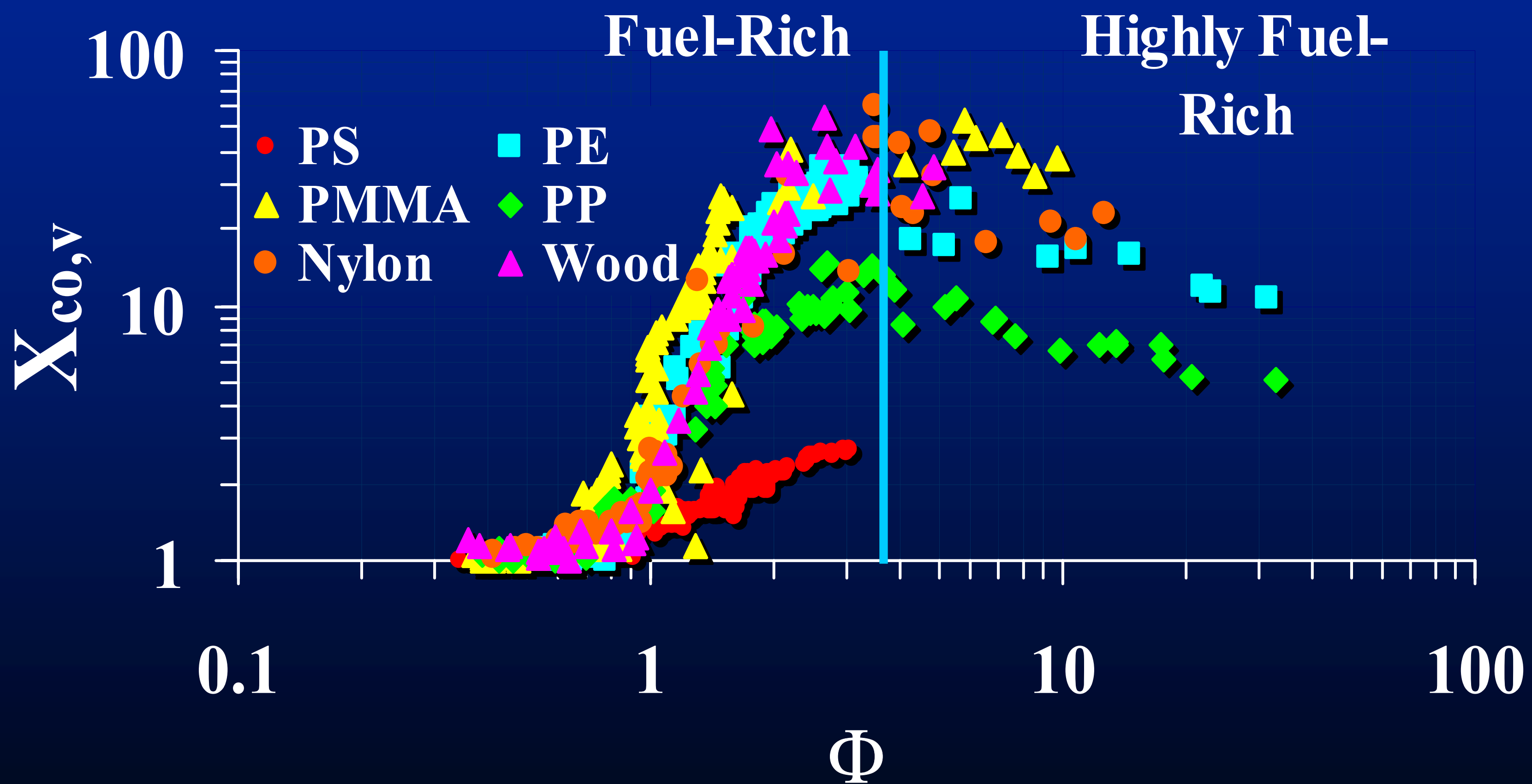
- Concentration of a product:

$$C_{j,v} = (M_a / M_j)[\, \dot{m}_j /(\dot{m}_a + \dot{m}_f)]$$

$$m_j = y_j \dot{m}_f \qquad X_{j,v} = y_{j,v} / y_{j,\infty}$$

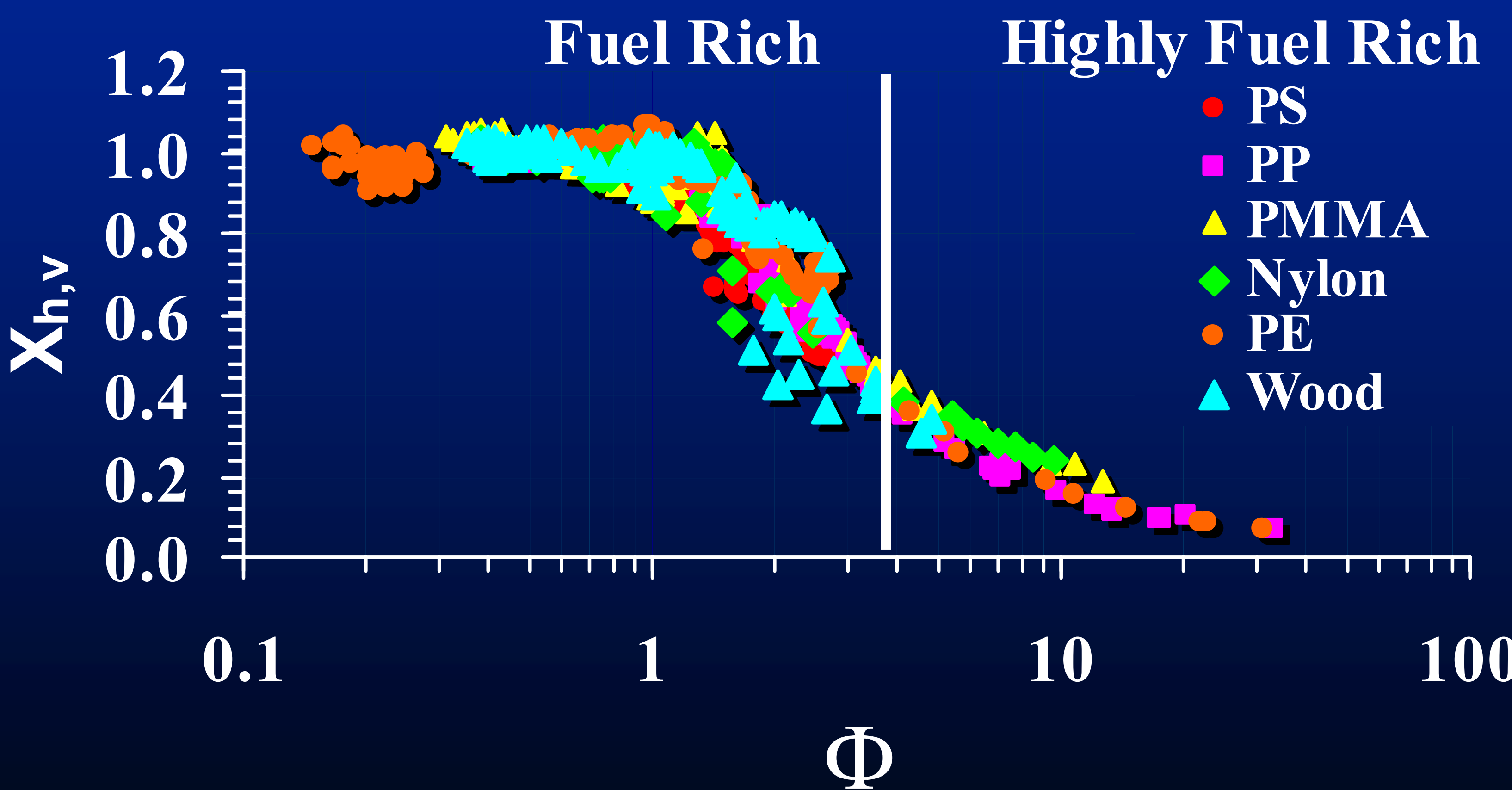
VENTILATION CORRECTION FACTOR FOR CO

$$X_{co,v} = y_{co,v} / y_{co,\infty}$$



VENTILATION CORRECTION FACTOR FOR EFFECTIVE (CHEMICAL) HEAT OF COMBUSTION

$$X_{h,v} = \Delta H_{ch,v} / \Delta H_{ch,\infty}$$



PRODUCT CONCENTRATION

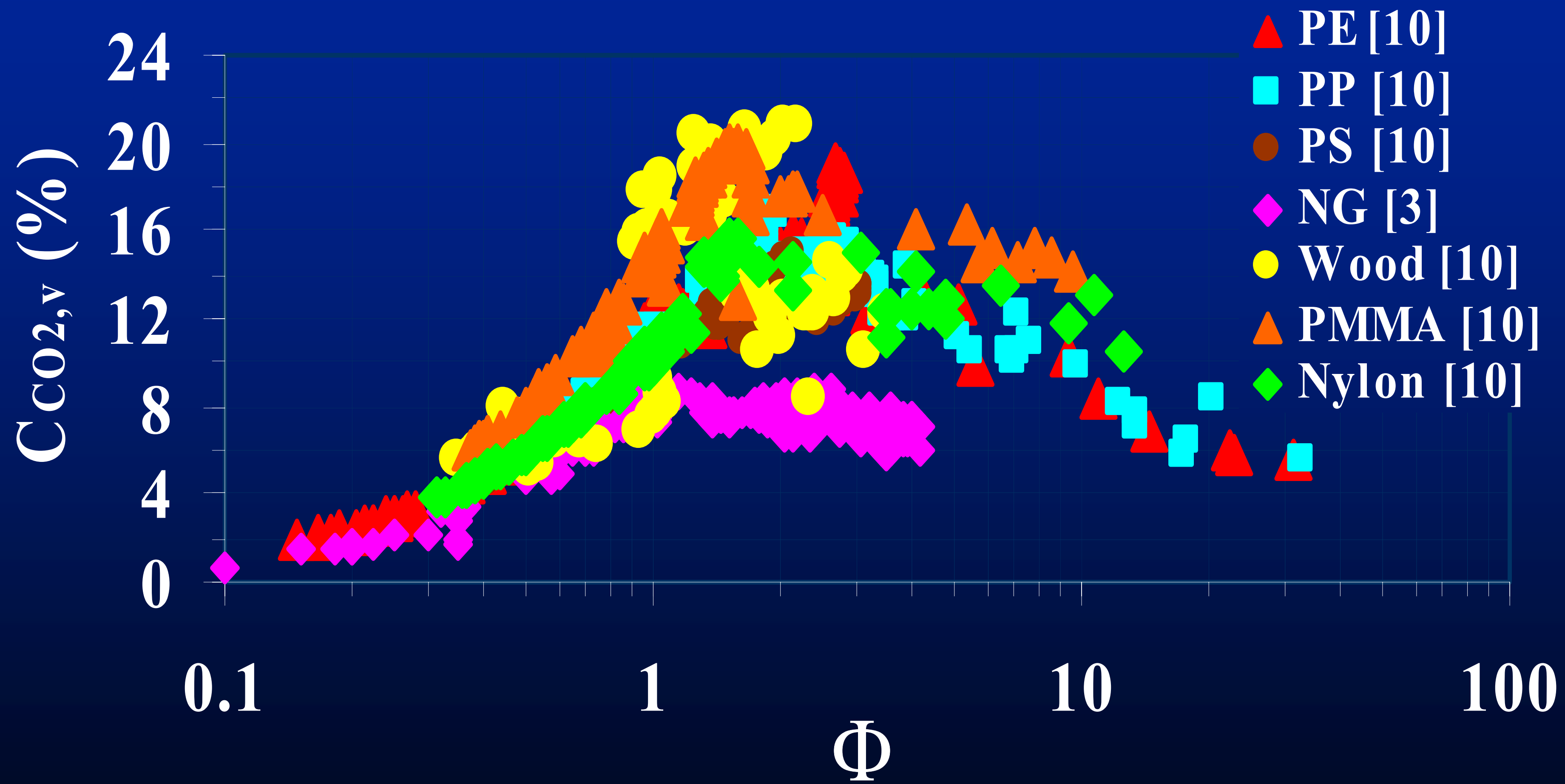
- **Ventilation Correction Factor**

$$X_v = 1 + [\alpha / \exp(\beta \Phi)^{-\xi}]$$

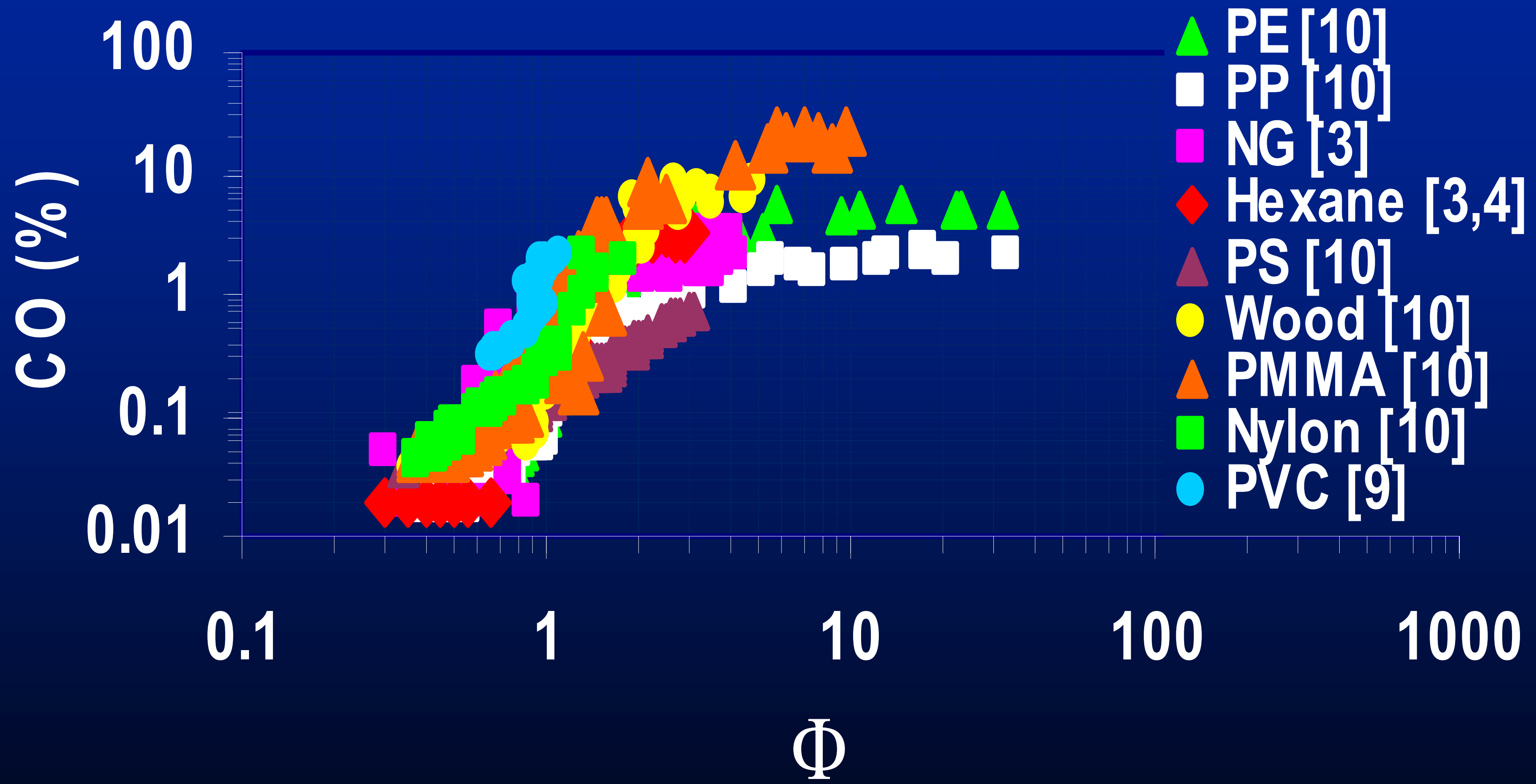
- **Concentration**

$$C_{j,v} = [(M_a / M_j) X_{j,v} \{ y_{j,\infty} /(s_a + \Phi)]\Phi$$

CO_2 CONCENTRATION VERSUS EQUIVALENCE RATIO



CO CONCENTRATION VERSUS EQUIVALENCE RATIO

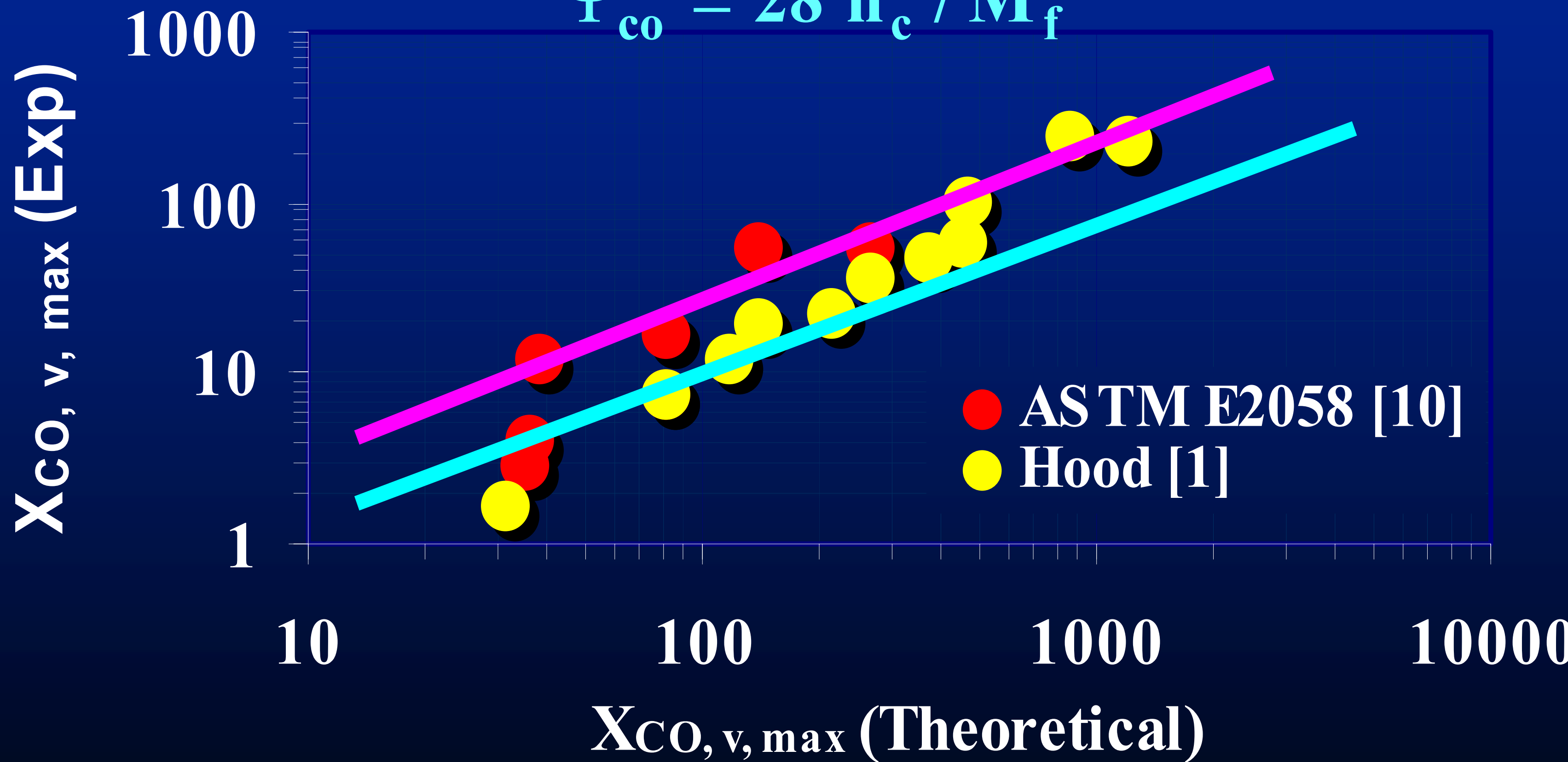


Experimental Versus Theoretical CO Yields

$$X_{co,v,max}(Exp) = y_{co,v,max} / y_{co,\infty}$$

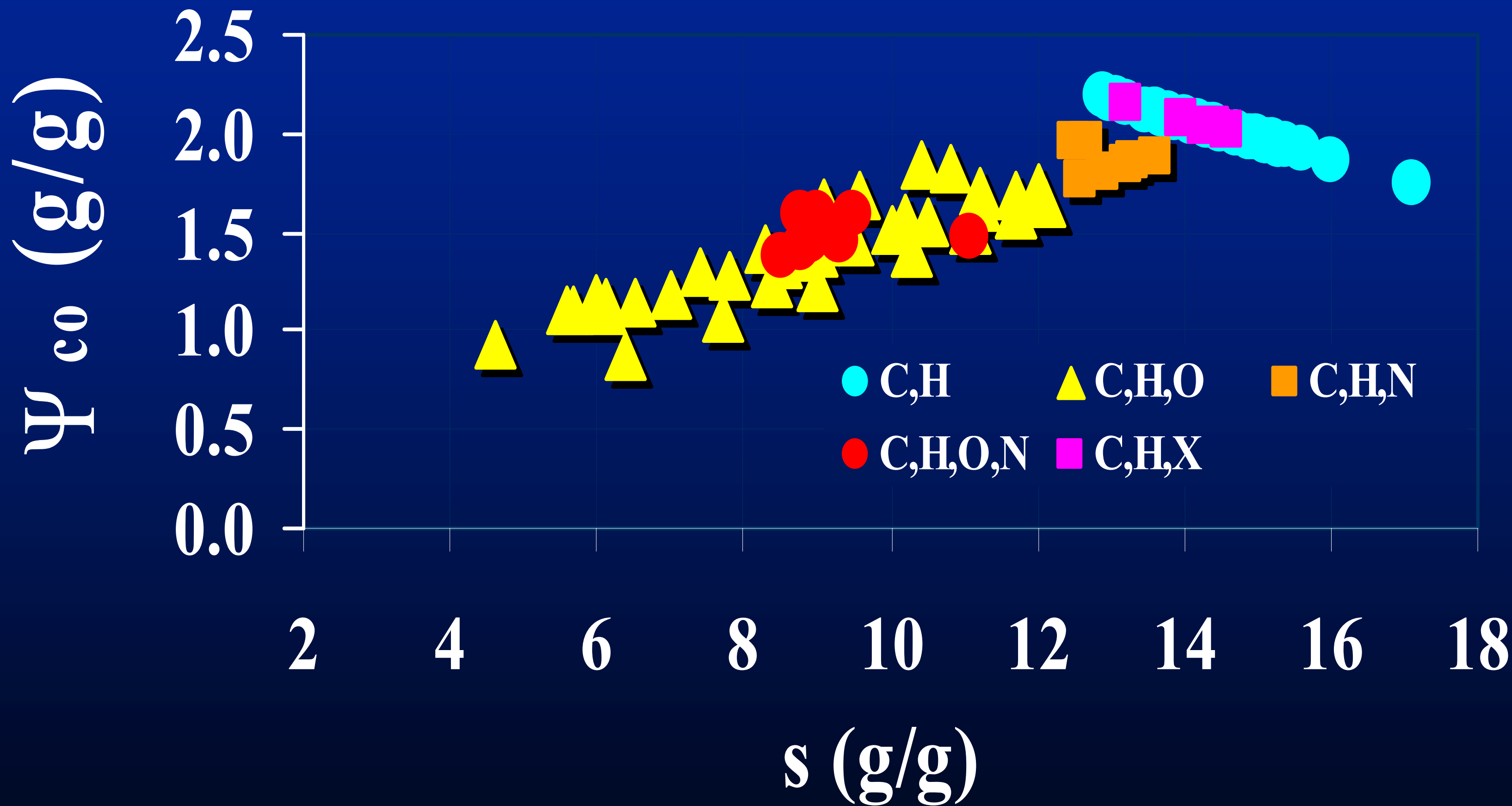
$$X_{co,v,max}(Theoretical) = \Psi_{co} / y_{co,\infty}$$

$$\Psi_{co} = 28\, n_c / M_f$$

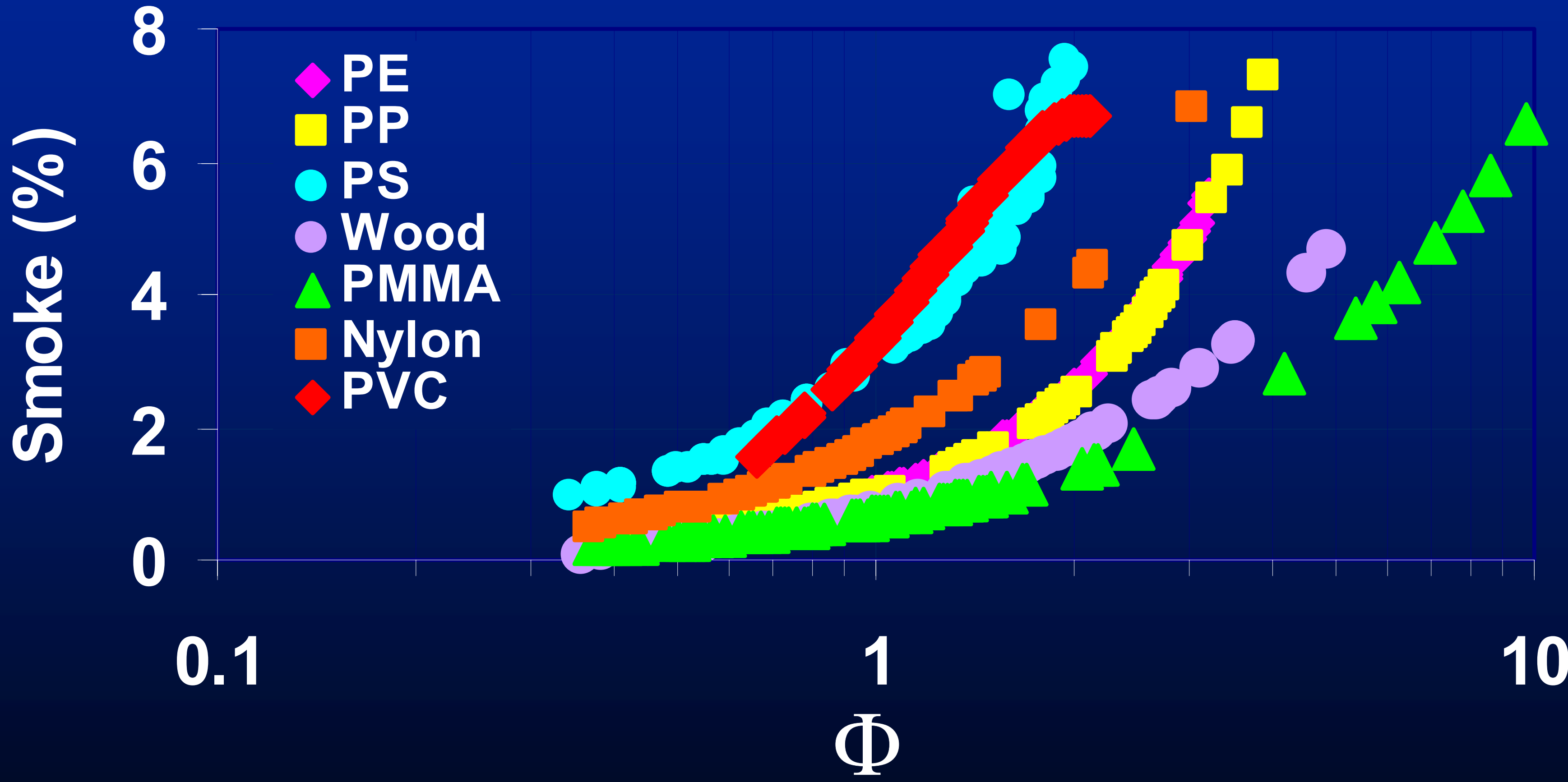


STOICHIOMETRIC CO YIELD VERSUS MASS AIR-TO-FUEL RATIO

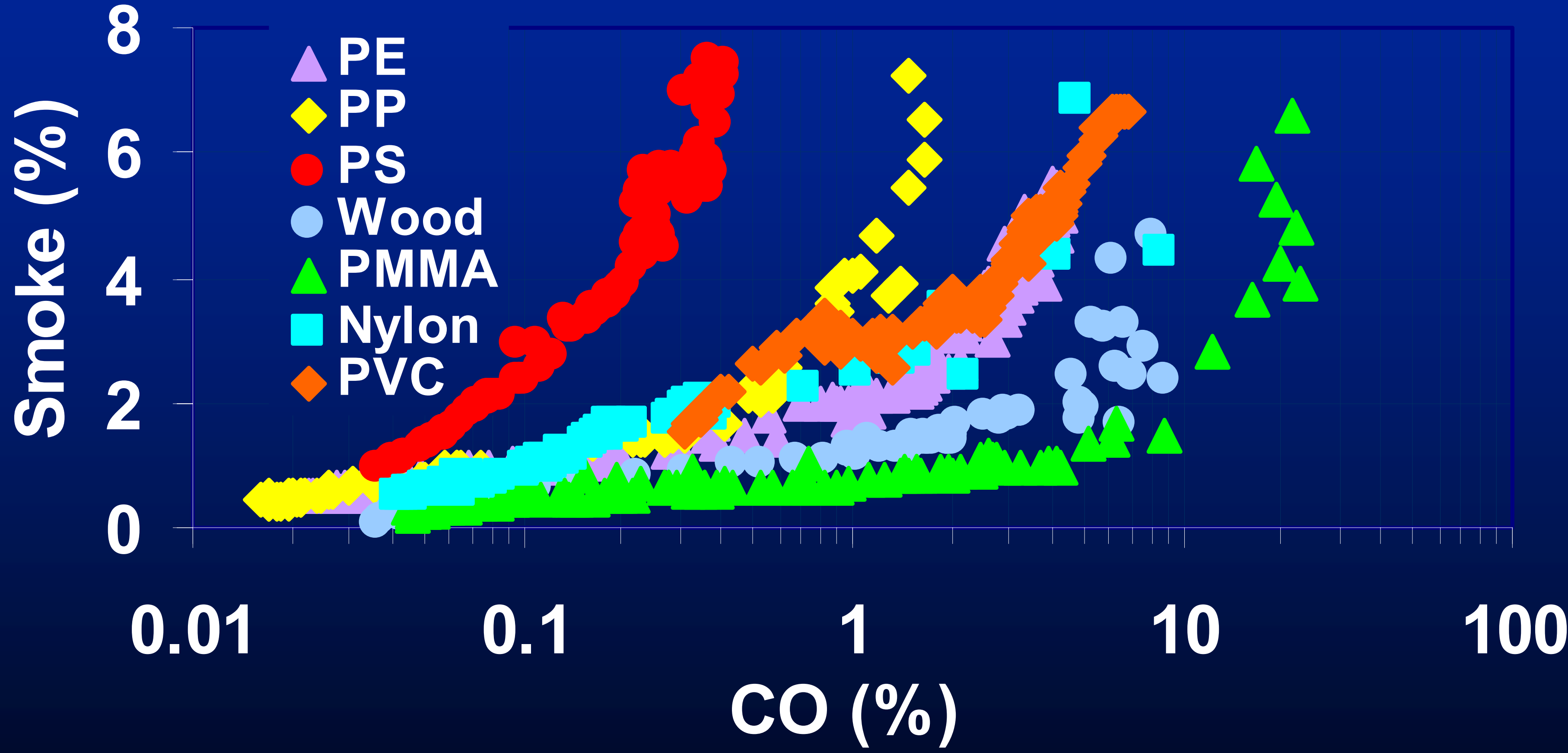
$$\Psi_{co} = 28\ n_c\ /\ M_f$$



SMOKE CONCENTRATION VERSUS EQUIVALENCE RATIO



SMOKE VERSUS CO CONCENTRATION



Smoke Point and Generation Efficiencies of Smoke and CO

- Carbon Monoxide

$$y_{co,\infty} / \Psi_{co}$$

$$- [0.0086 \ln(L_{sp}) + 0.131]$$

- Smoke

$$y_{s,\infty} / \Psi_{s}$$

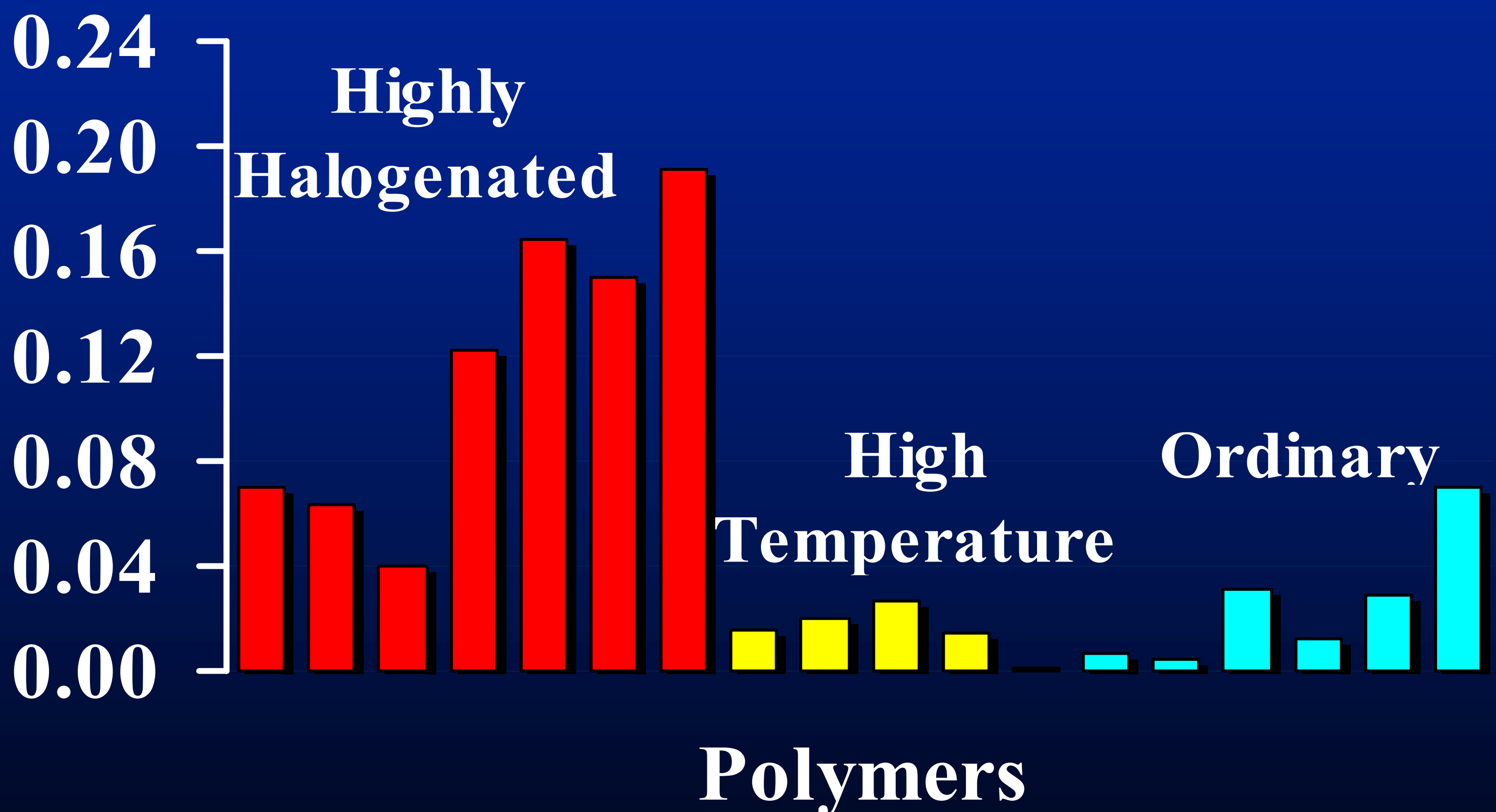
$$- [0.0515 \ln(L_{sp}) + 0.0700]$$

POLYMER COMPOSITIONS

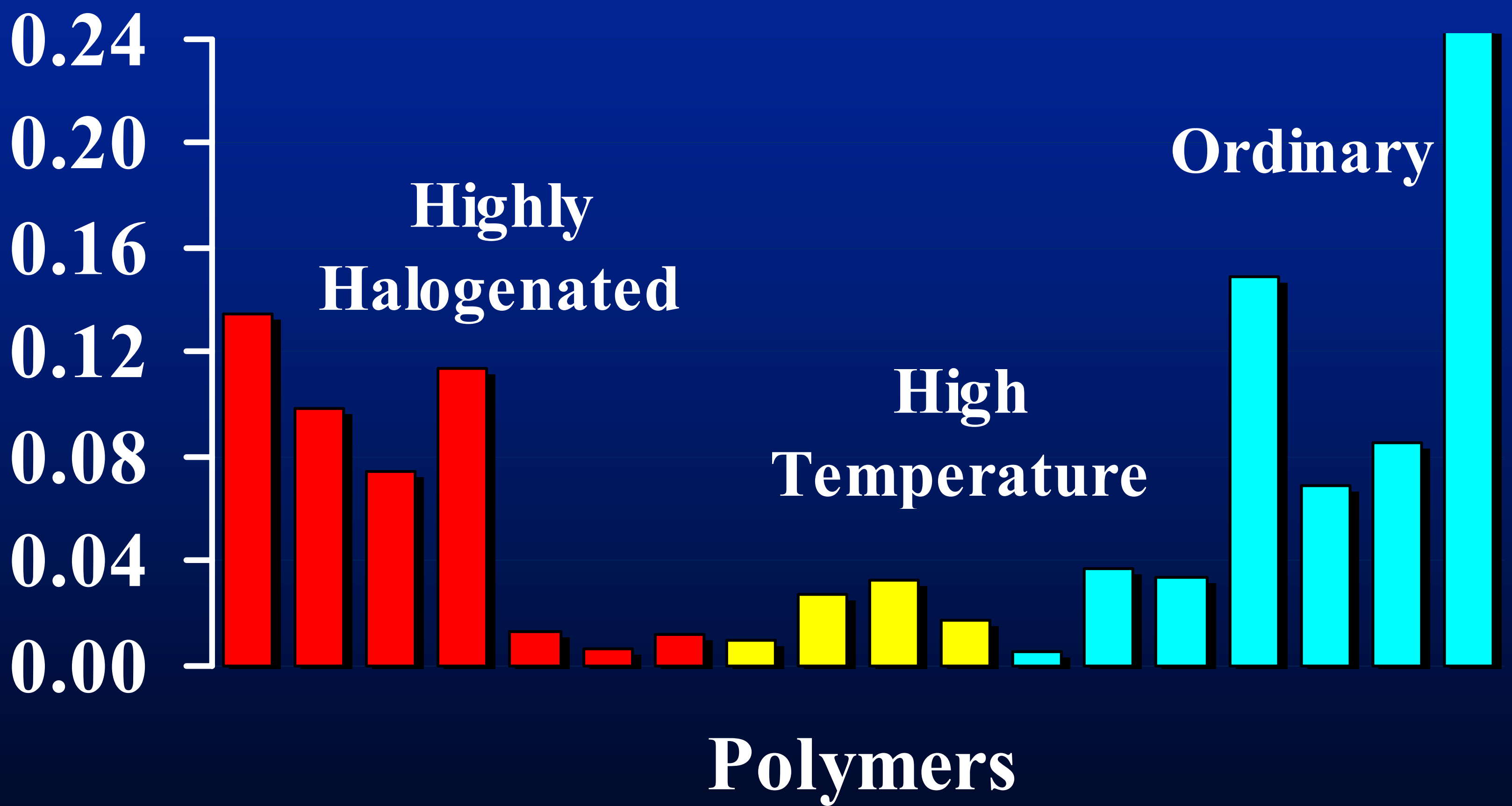
Polymers	Composition
Highly Halogenated	
PVDF	CHF
ETFE	CHF
ECTFE	$CHF_{0.75}Cl_{0.25}$
TFE	CF_2
CTFE	$CF_{1.5}Cl_{0.50}$
CPVC	$CH_{1.3}Cl_{0.70}$
PVC	$CH_{1.5}Cl_{0.50}$

Polymers	Composition
High Temperature	
PEEK	$CH_{0.63}O_{0.16}$
PPS	$CH_{0.67}S_{0.17}$
PBI	$CH_{0.67}N_{0.33}$
PEI	$CH_{0.68}N_{0.05}O_{0.14}$
Ordinary	
PE	CH_2
PS	CH
PMMA	$CH_{1.6}O_{0.4}$
Wood	$CH_{1.7}O_{0.74}N_{0.002}$
Nylon	$CH_{1.8}O_{0.17}N_{0.17}$

$$y_{co,\infty} / \Psi_{co}$$



$y_{smoke,\infty} / \Psi_{smoke}$



LIMITATIONS, DEFICIENCIES AND SPECIFIC NEEDS TO IMPROVE THE GER CONCEPT

- **Definition of fire growth and spread for the ventilation-controlled fires using better definitions of fuel flow rate ($X_{f,v}$) and ignition ($X_{ig,v}$):**

$\dot{q}_f$

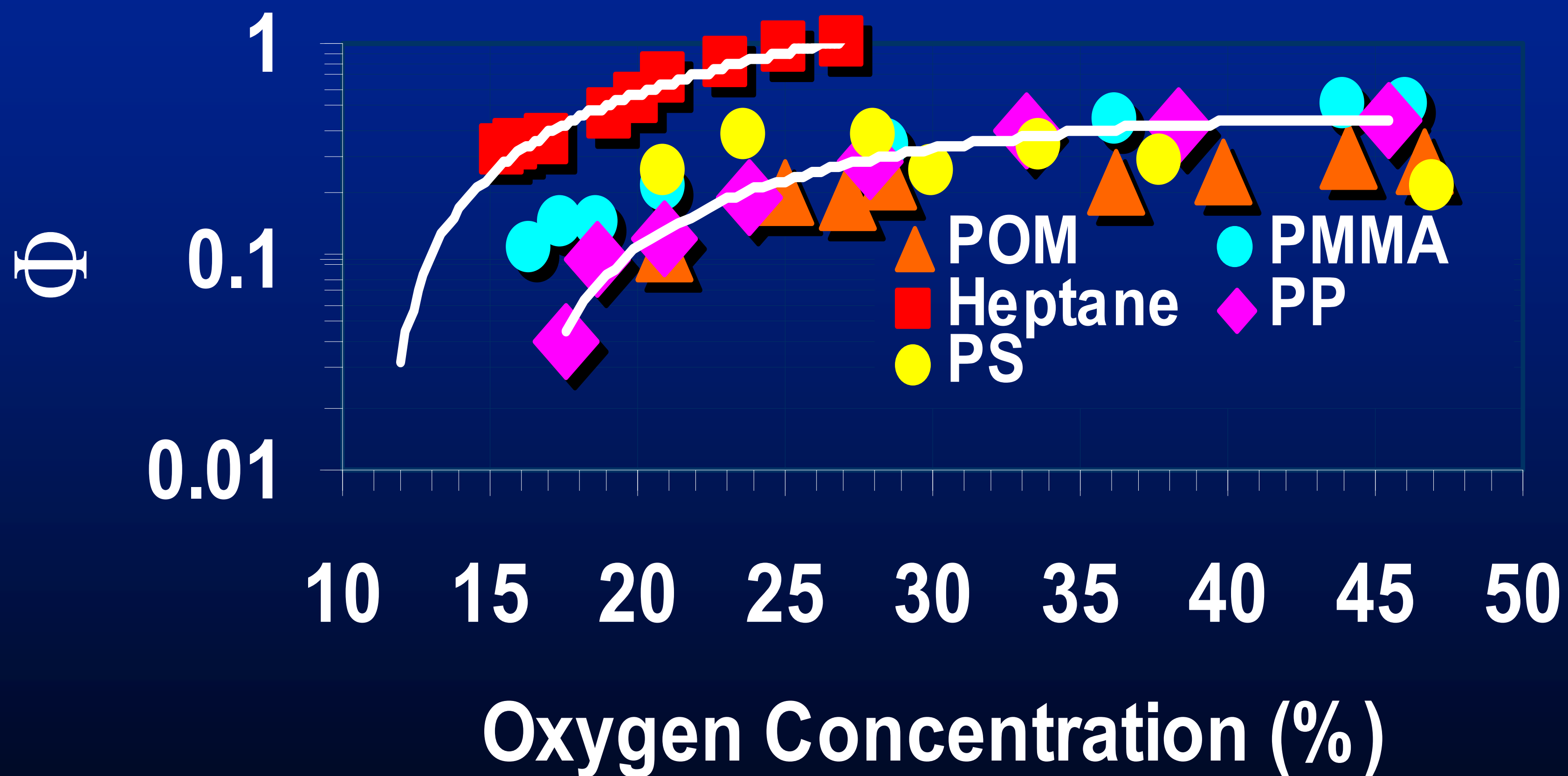
$$X_{f,v} = \dot{m}_{f,v} / \dot{m}_{f,\infty}$$

$$X_{ig,v} = t_{ig,v} / t_{ig,\infty}$$

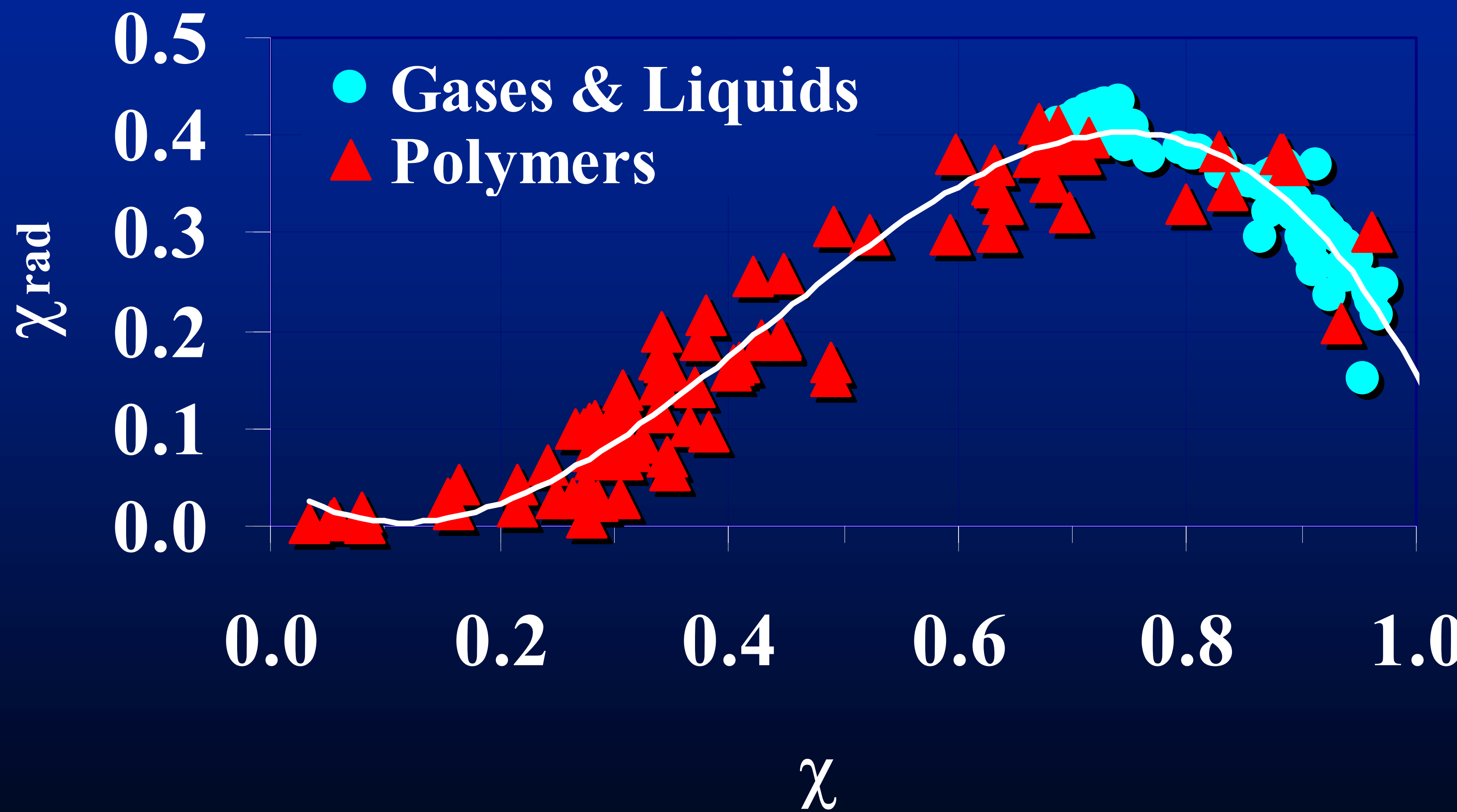
LIMITATIONS, DEFICIENCIES AND SPECIFIC NEEDS TO IMPROVE THE GER CONCEPT

- Generalized relationships between X and generic fuels (smoke point, s, $\dot{q}''_{f}\Psi_{j}$, ΔH_g, ,χ, χ_{con} and χ_{rad});
- Experimental validation of the concentration and gas temperature relationships;
- Examination of the smoke characteristics for highly fuel-rich ventilation-controlled combustion conditions using smoke particulate analyzers, FTIR etc.

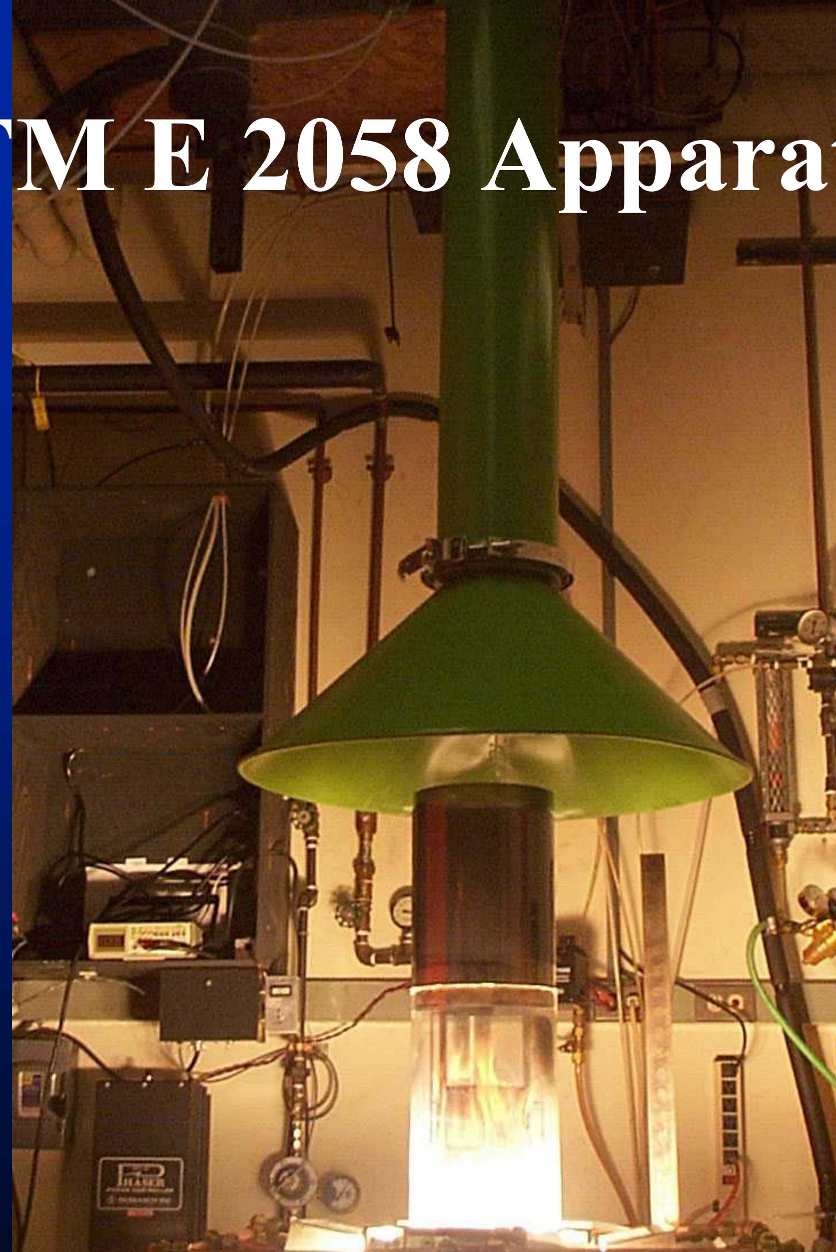
EQUIVALENCE RATIO VERSUS OXYGEN CONCENTRATION



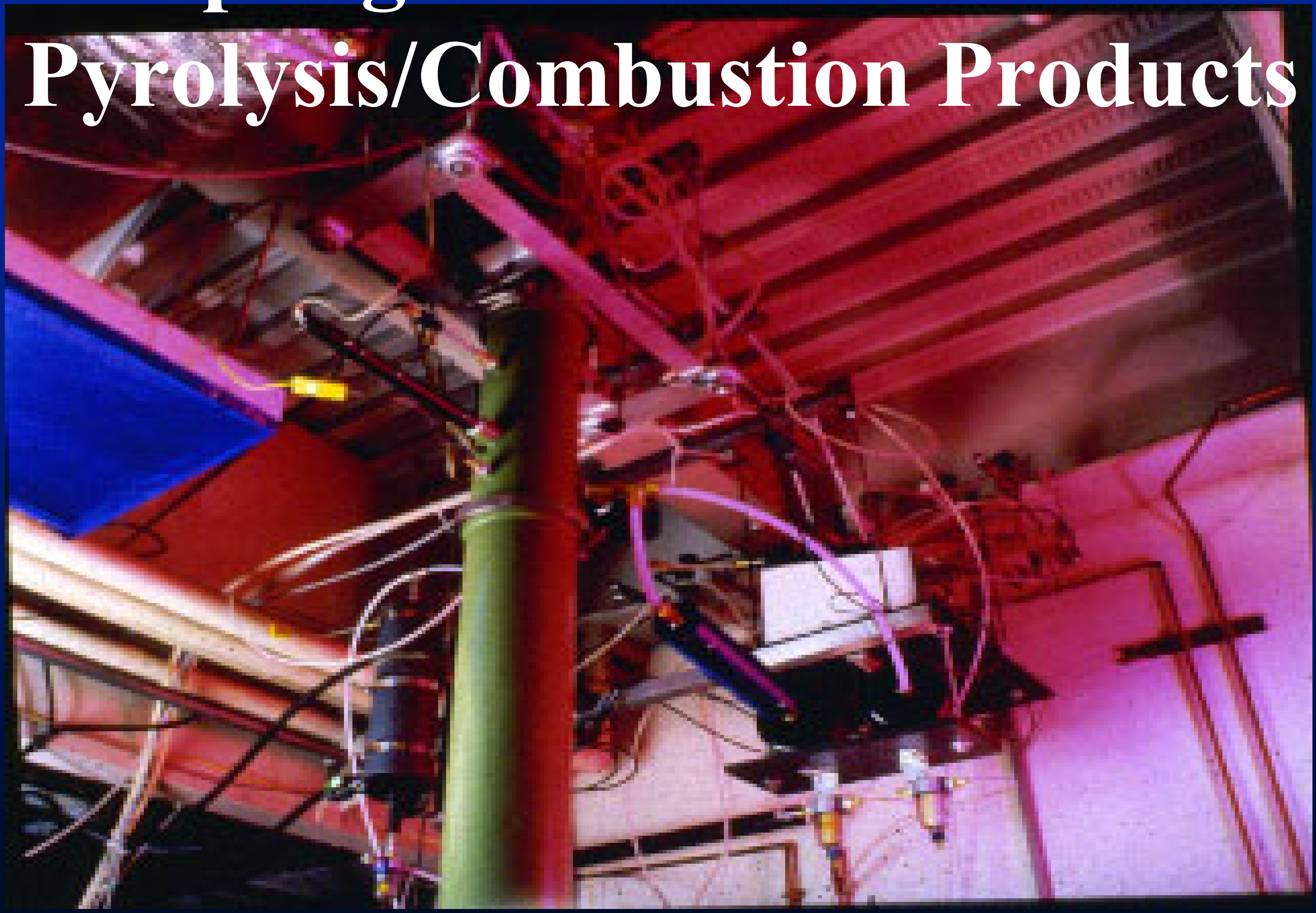
Combustion Efficiency and Its Radiative Component



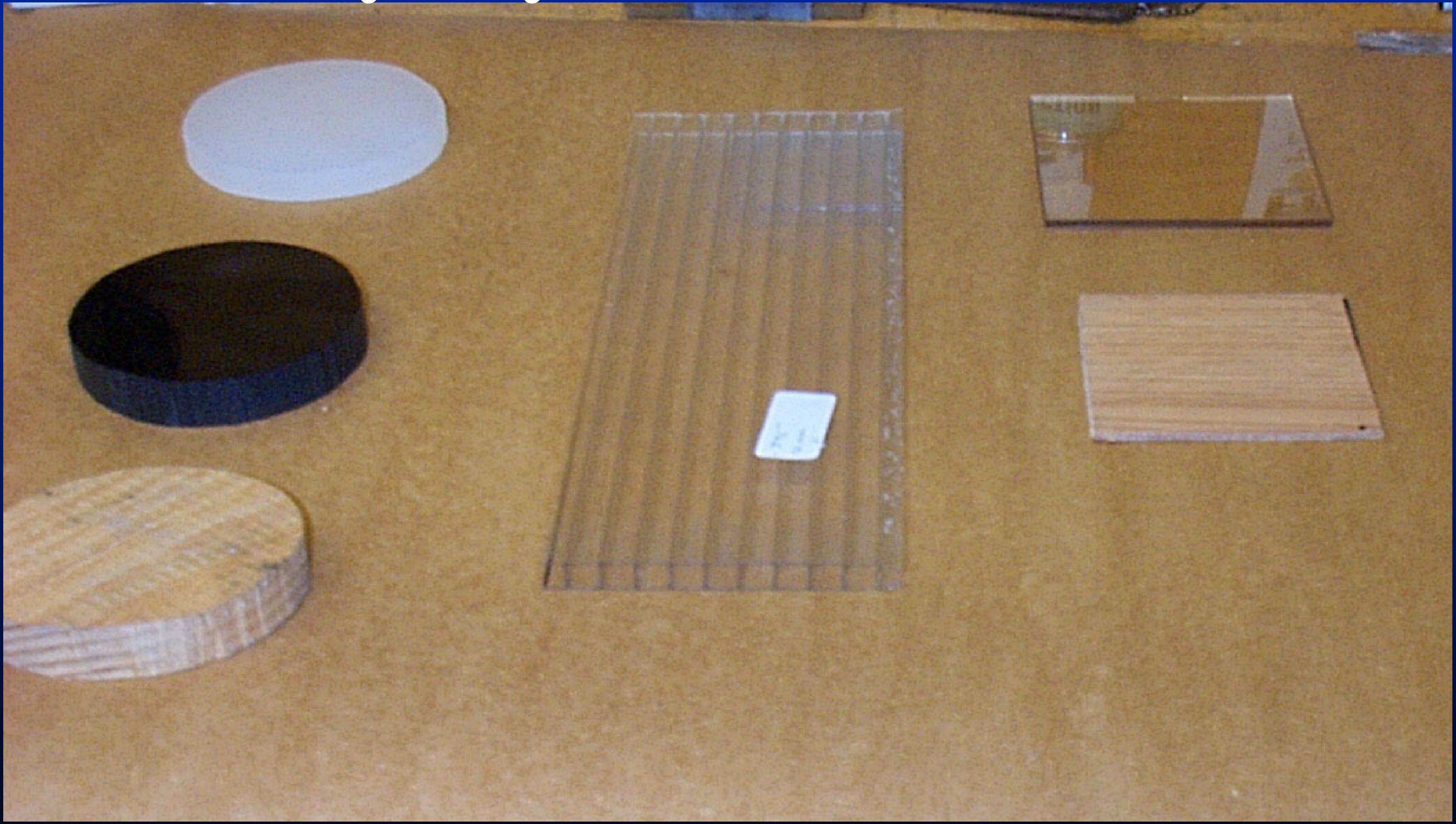
ASTM E 2058 Apparatus



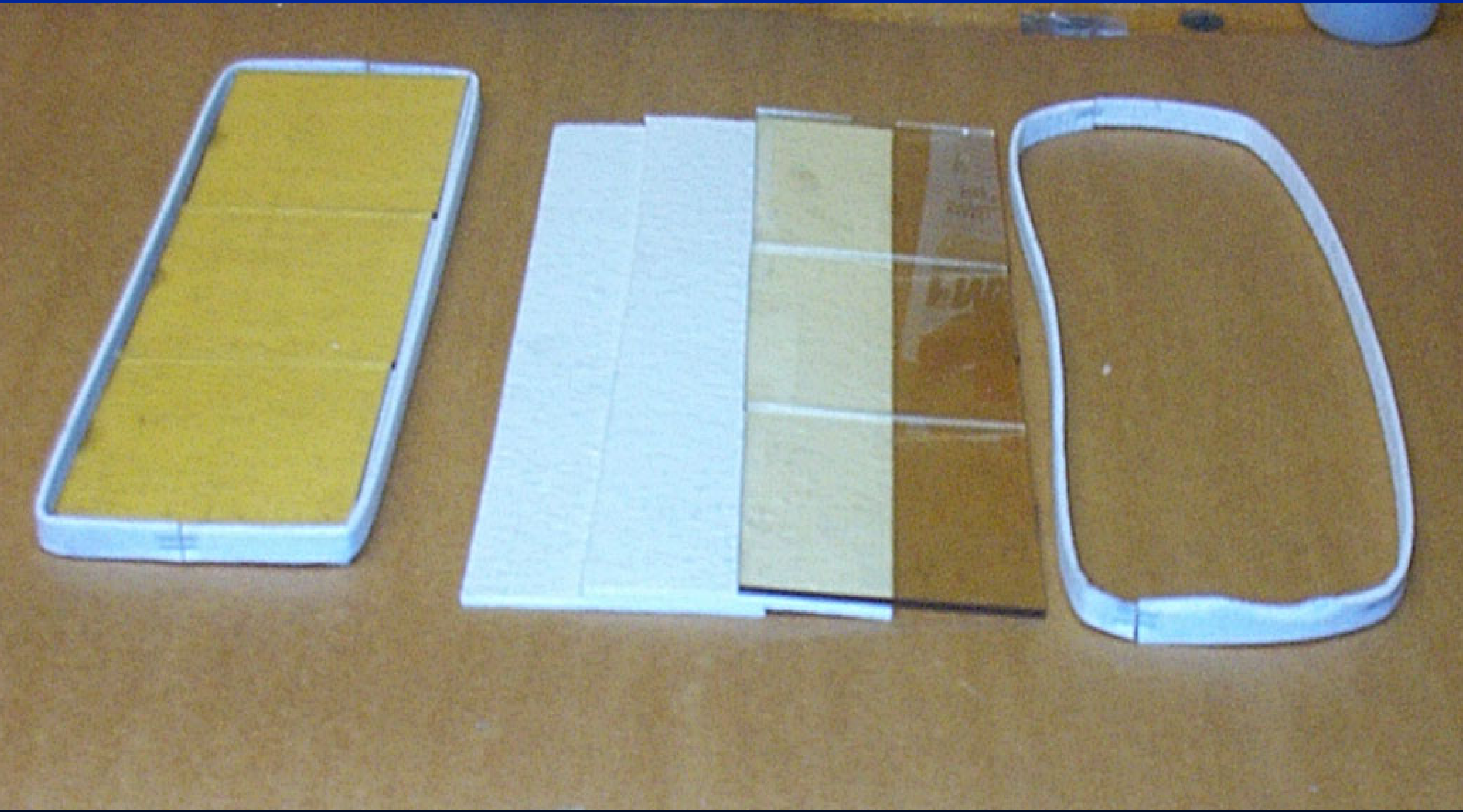
ASTM E 2058 Apparatus: Sampling for Pyrolysis/Combustion Products



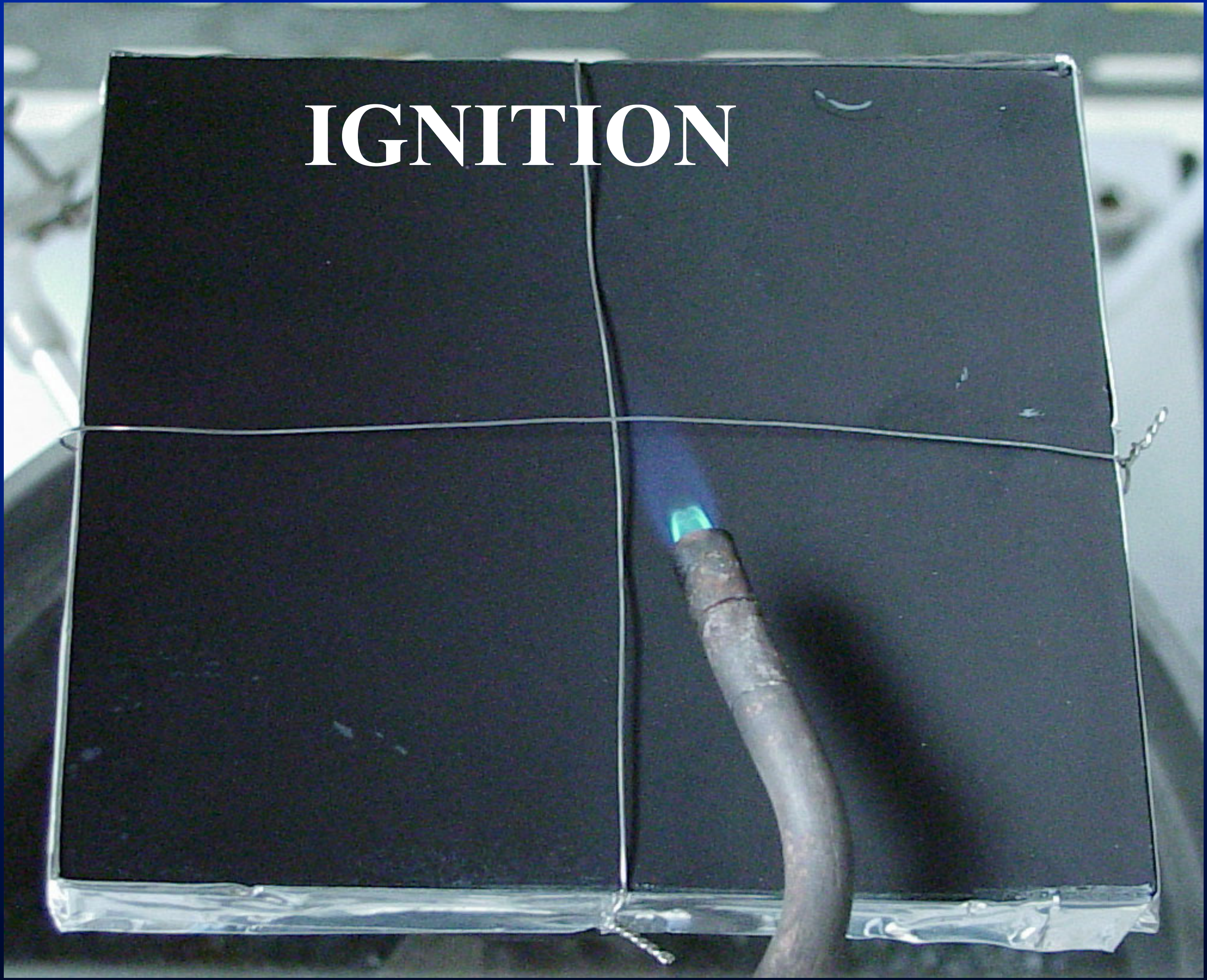
Samples: Ignition, Combustion and Pyrolysis



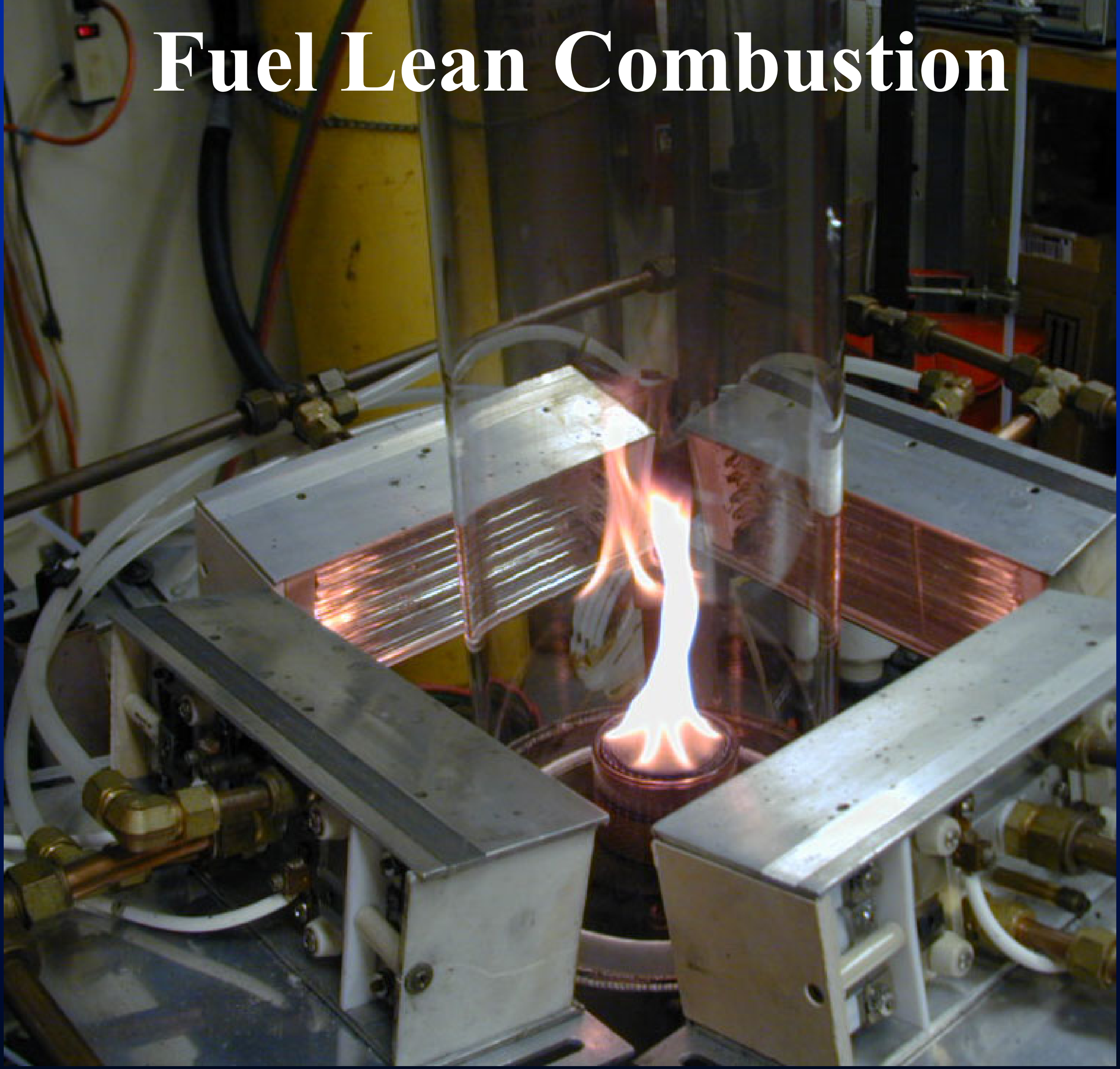
Samples for Fire Propagation



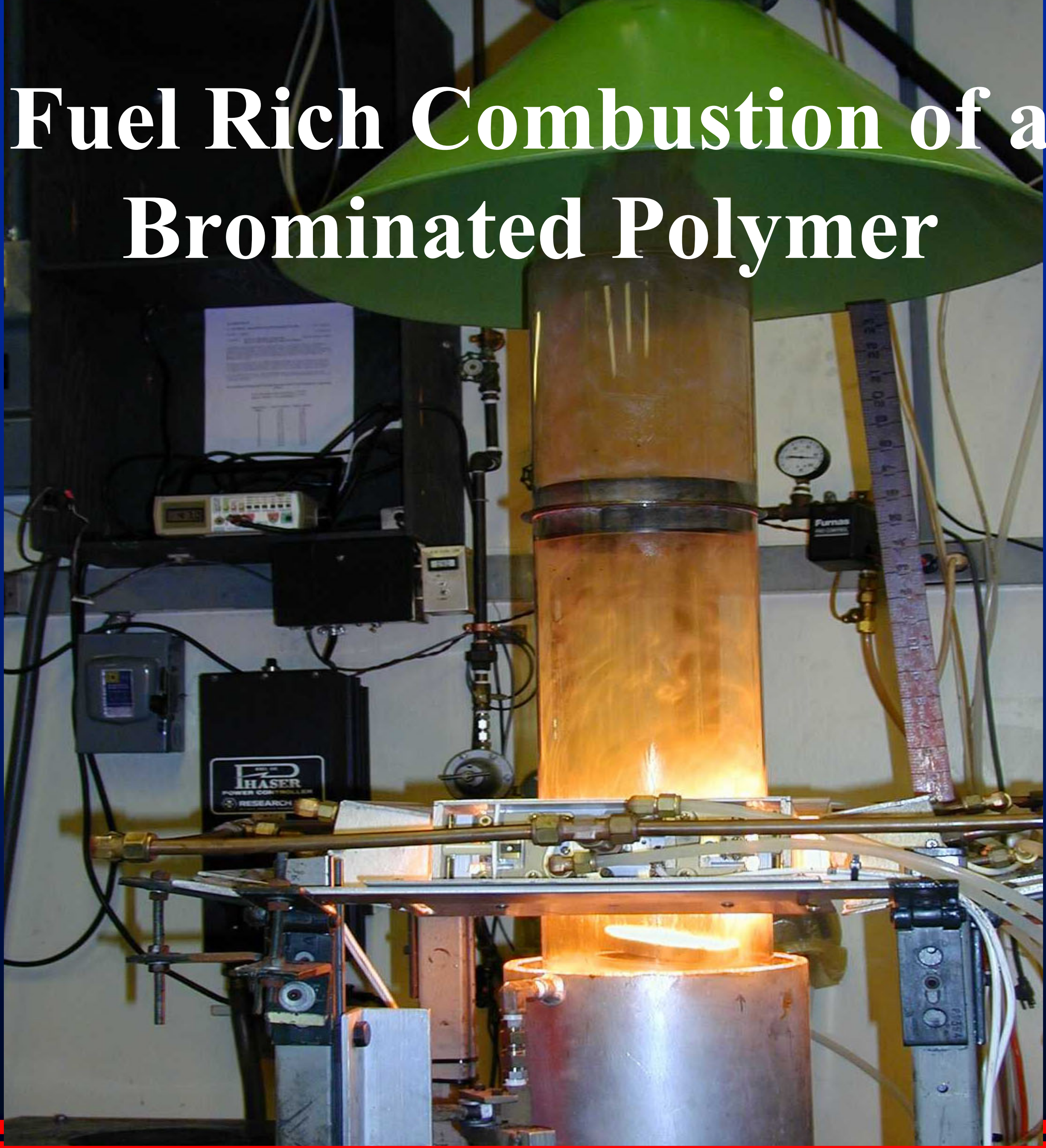
Non-Flaming Combustion


IGNITION

Fuel Lean Combustion



Fuel Rich Combustion of a Brominated Polymer



Highly Fuel-Rich Combustion

Highly Fuel Rich Combustion