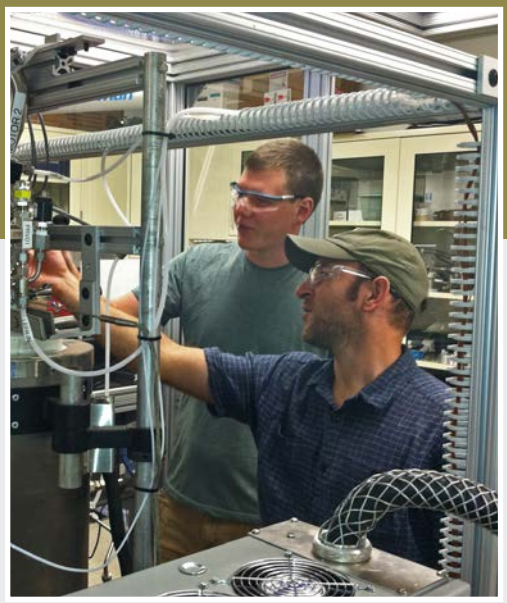
Laminar Entrained Flow Reactor

Investigating the core principles of *in situ* and *ex situ* catalytic fast pyrolysis of biomass



Grant Buckingham (L) and Mark Jarvis (R) discuss the operation of the biomass feed system.
Photo by David Robichaud, NREL 28346

The Laminar Entrained Flow Reactor (LEFR) is a modular, lab-scale, single-user reactor for the study of catalytic fast pyrolysis (CFP). This system can be employed to study a variety of reactor conditions for both *in situ* (in place) and *ex situ* (out of place) CFP.

NREL's custom-built LEFR system continuously produces char-free pyrolysis vapors and delivers them to a second, independently controlled, catalytic reactor. The secondary reactor can be configured as a 4-channel fixed bed or drop tube reactor. Catalyst performance and deactivation can be studied at small scale, with real biomass pyrolysis vapors. Used catalyst is removed from the vapor stream for further analysis or regeneration. Solid char, liquids, and the outlet gas yields are measured to provide a quantitative mass balance.

High Level Capabilities

Laminar Entrained Flow Reactor features:

- Fast screening catalysts
- Online, real-time measurements of pyrolysis vapors (MBMS/Molecular Beam Mass Spectrometer, NDIR, and microGC)
- Collection of condensed bio-oils for independent characterization
- Fully automated, Opto 22 control system for minimal user interaction.

MBMS applications include:

- Analytical pyrolysis
- Catalyst screening
- Comparison of *in situ* versus *ex situ* CFP
- Fundamental studies of thermochemical conversion of biomass
- Characterization of hot gas filtering.

LEFR Specifications	
Systems	0-50 psig, 300-700°C. Inlets for gaseous co-feeds (H_2, alkanes). Fully automated, Opto 22-controlled system.
Analytics	Quantitative: NDIR (CO, CO_2, CH_4), µGC (C_2-C_5). Qualitative: MBMS/PIMS (aromatics, carbohydrates).
Particle sizes	0.1 to 0.5-mm particles can be fed into system.
Feed rates	3-5 g/hour continuous feed. 100+ hours of continuous operation.

Glass condensers collect upgraded product vapors from the reactor for oil characterization.
Photo by David Robichaud, NREL 28347

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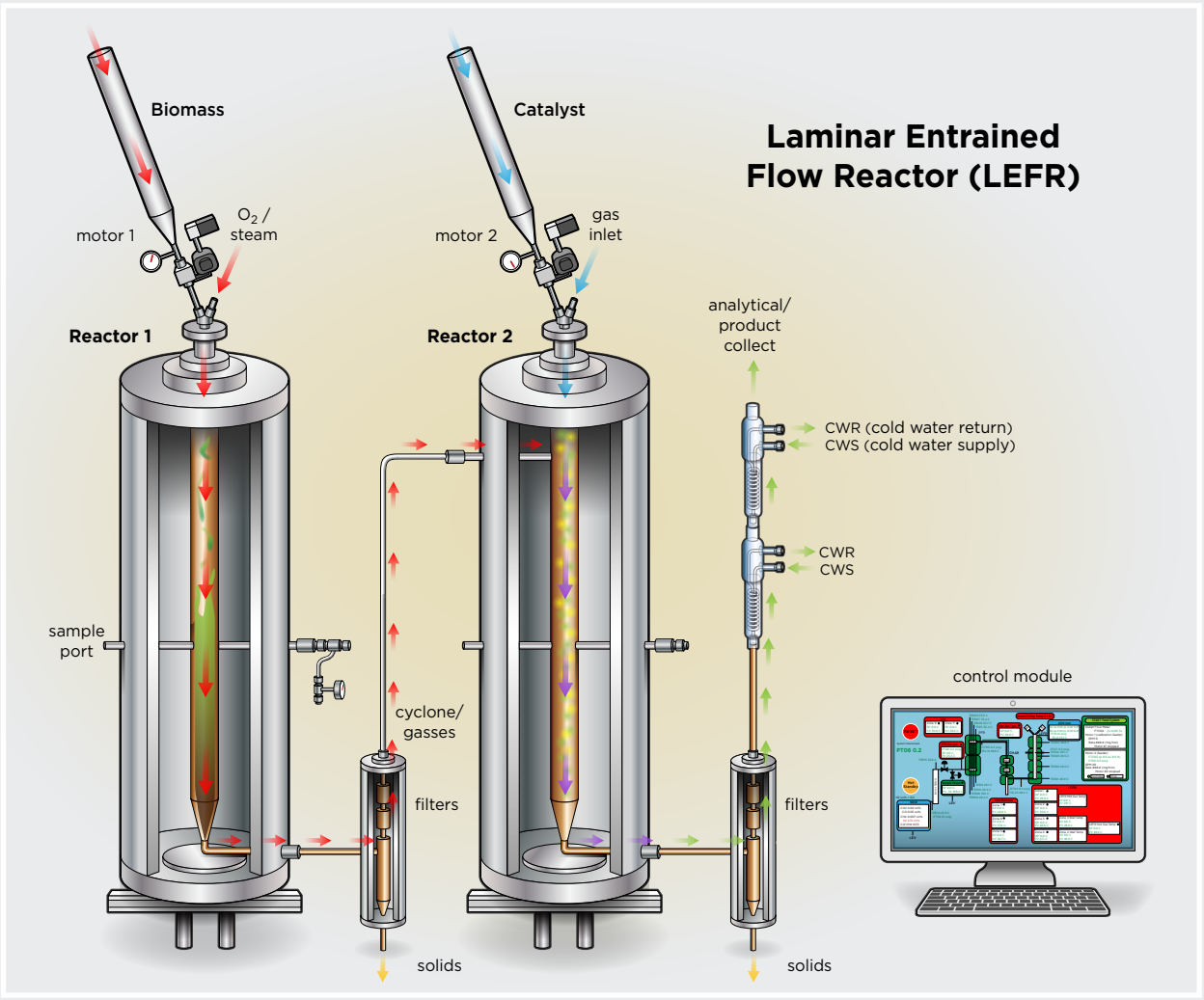

Schematic diagram of the LEFR system. This modular system allows for testing a variety of configurations for *in situ* and *ex situ* CFP. *Illustration by Al Hicks, NREL.*

Applications

In situ versus *ex situ* CFP

- Dual feed system allows for *in situ* CFP
- *Ex situ* CFP possible using hot gas filtration, packed beds, and entrained flow arrangements.

Testing hot gas filtration on catalyst lifetime and product distribution

- Using *ex situ* CFP, hot gas filters (50 to 200µm-pores) can be used to remove fine particulate and soot molecules. Effect on catalyst coking rates, and activity can be investigated
- Gas phase sampling using MBMS/PIMS. Condensed-phase product slate using GCMS and NMR spectroscopy.

Fundamental studies of thermochemical reactions and kinetics

- Identification of pyrolysis and CFP mechanisms and kinetics
- Reaction parameter screening for engineering scale up
- Validation of CFD modeling efforts.

Publications

Jarvis, M., et al., (2011) "Elucidation of Biomass Pyrolysis Products Using a Laminar Entrained Flow Reactor and Char Particle Imaging." Energy Fuels (25); pp. 324-336.

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