

HYDROGEN FROM BIOMASS FOR URBAN TRANSPORTATION

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**DOE Hydrogen Program Review
Project ID #: TVP1**

This presentation does not contain any proprietary or confidential information

Overview

Timeline

- Project start date: 2003
- Project end date: 2005
- Percent complete: 100%

Barriers

- Feedstock cost and availability
- Efficiency of pyrolysis and reforming technologies
- Durable, efficient and impurity tolerant catalysts
- Hydrogen separation and purification
- Market and delivery

Partners

- National Renewable Energy Lab
- Eprida, Inc.

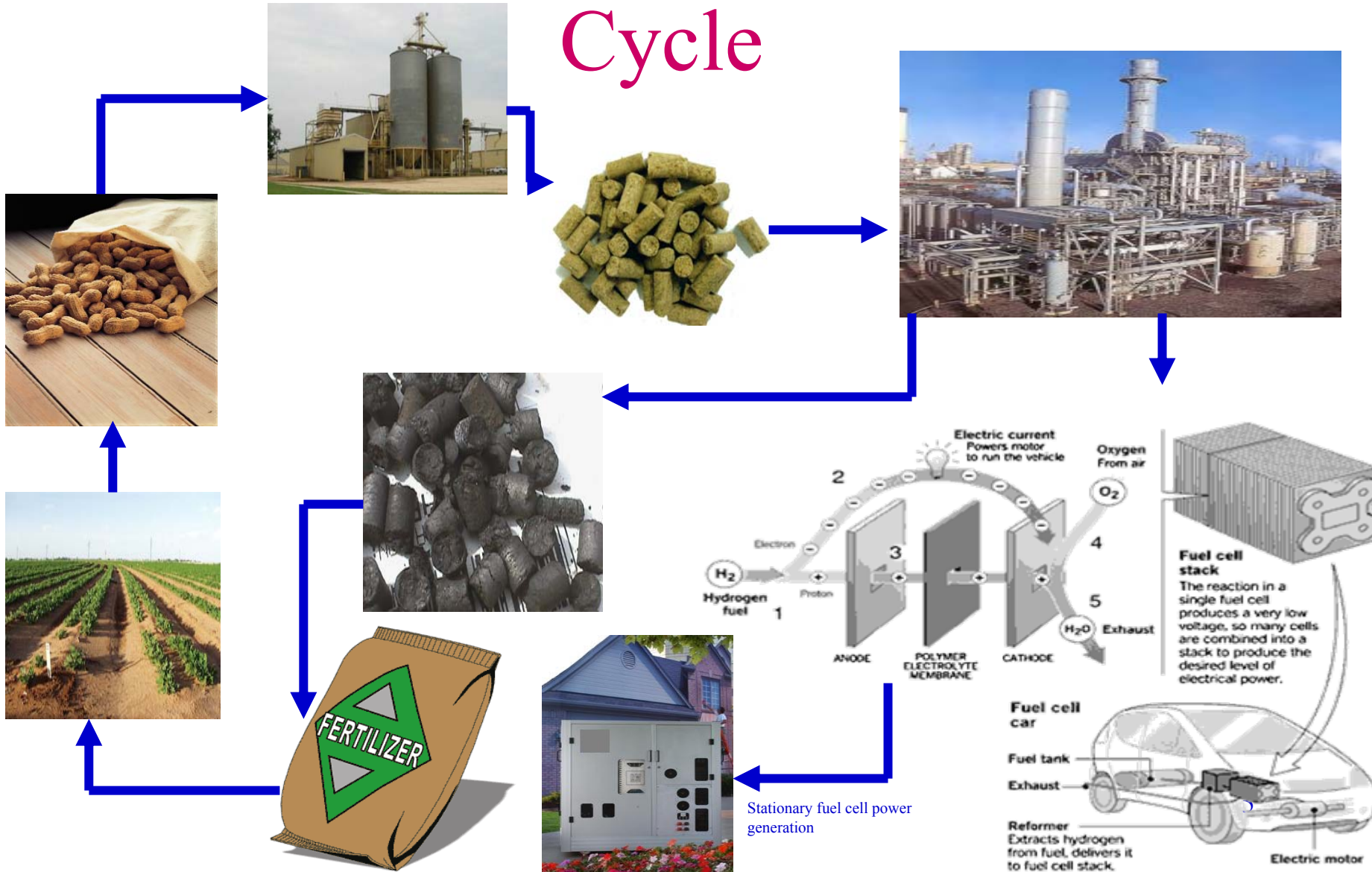
OBJECTIVES

- **Undertake the engineering research and pilot scale process development studies relating to:**
 - Production of hydrogen from biomass (e.g., agricultural residues) for \$2.90/kg H₂ by 2010; \$2.30 by 2015
 - Separation, safe storage and utilization of the hydrogen
 - Production and identification of uses of the co-products

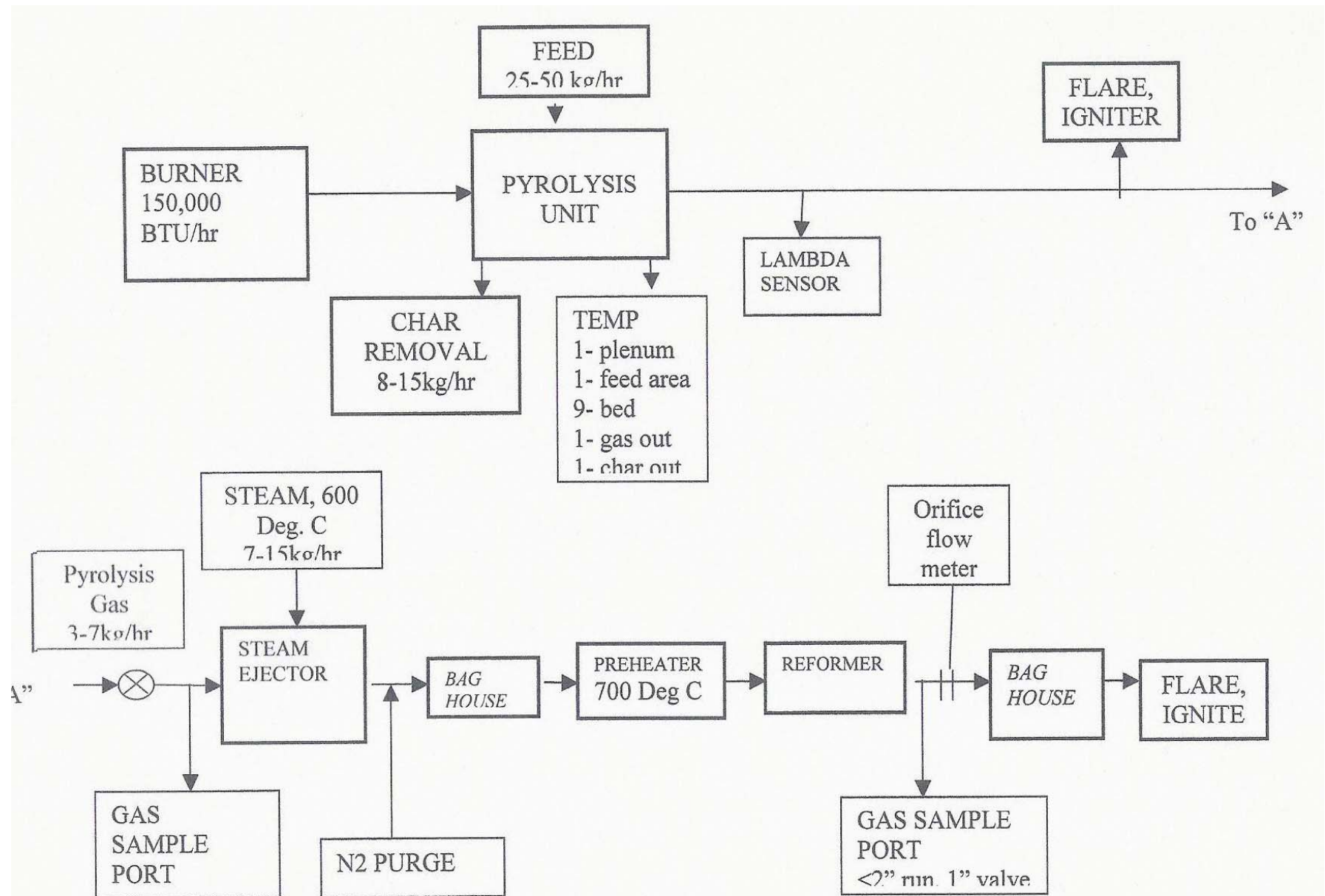
APPROACH

- **Develop process based on pyrolysis of biomass and steam reforming of pyrolysis vapors (bio-oils and gases).**
- **Perform catalytic steam reforming in a fluidized-bed (25-250 kg/day H₂ production)**
- **Conduct pyrolysis at: T: 500°C; P: 10 psig; Feed Rate: 50-500 kg/hr pelletized peanut shells**
- **Study reforming at: T: 850°C; P: 6 psig; H₂O/C = 5, Catalyst: nickel-based (300-500 microns)**

The Peanut Shell to Hydrogen Cycle



Schematic Flow Diagram of the Biomass Pyrolysis-Reformer Process



Photograph of Hydrogen Production System



Major Components



- Feeder & Pyrolysis Unit
- Superheater & Baghouse
- Pre-heater & Reformer
- Cooler & Condenser
- Control and Monitoring System

Hydrogen Production Control

Feed Logic On, Reformer 850C,

Links

- Digital Controls
- Thermocouples
- T-Couple Trend
- Machine
- Process Trend
- Pyrolysis Trend
- Baghouse Trend
- Preheater Trend
- Reformer Trend

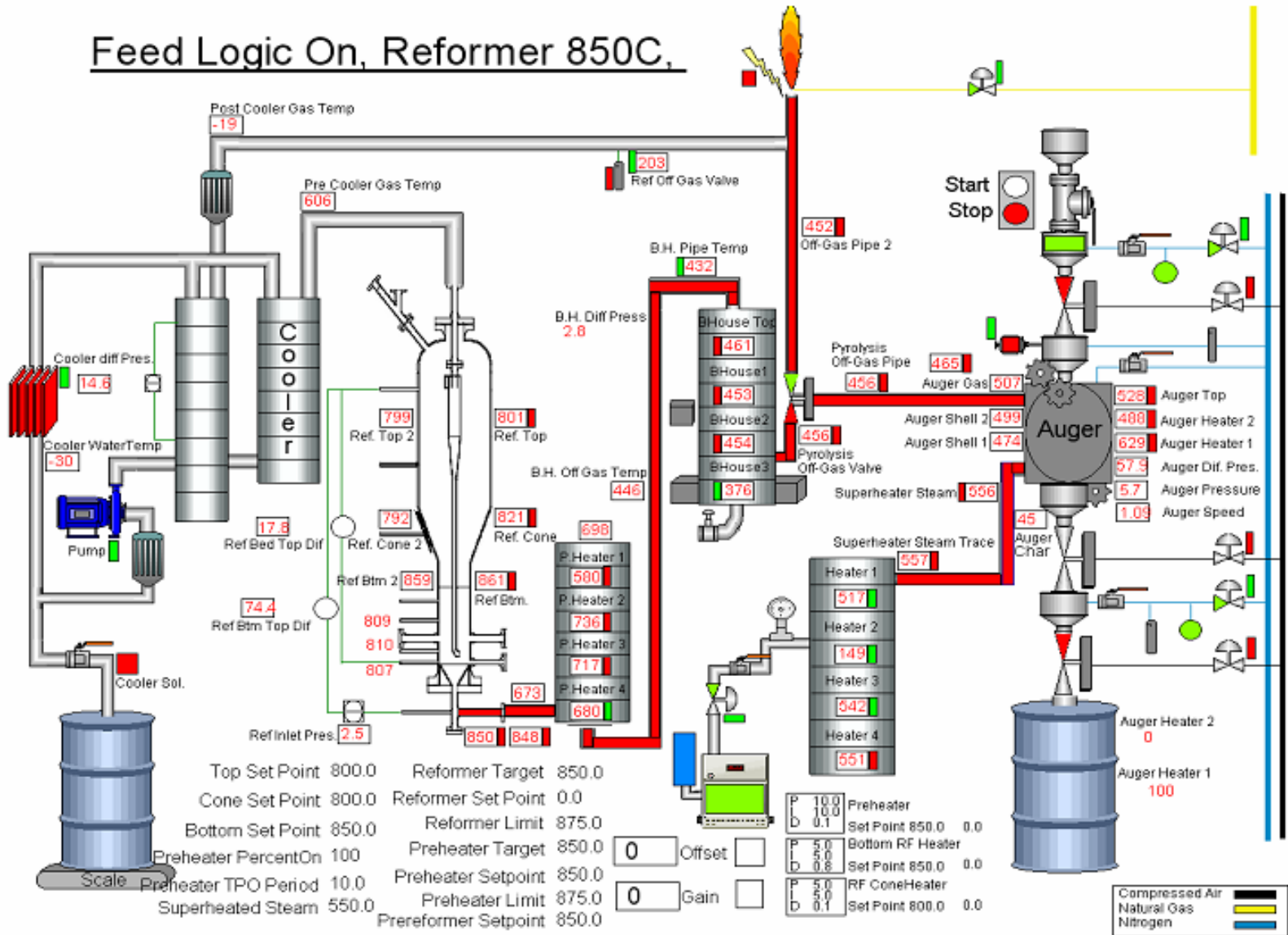
Modes

- Idle
- Heat Up
- Run
- Cool Down
- Shut Down
- Reset Flow Meter

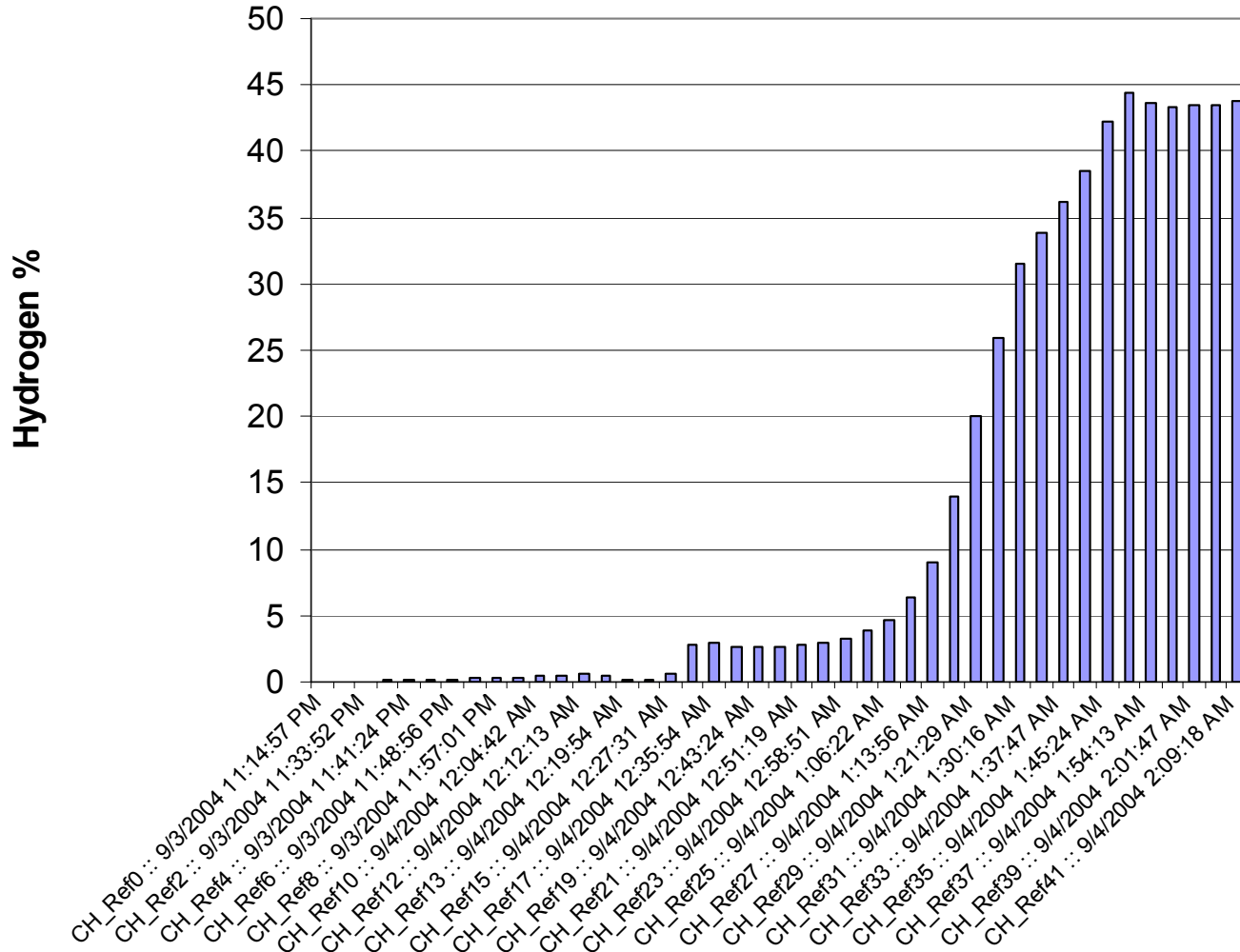
Boiler On ■

RUN

Water Flow Okay
1.06 Total Gal
17.68 kg/hr
Boiler Alerts
ALERT->Boiler rec
Low Water Alert
Alert->Steam Boil
Steam Pressure Error
Superheater Error



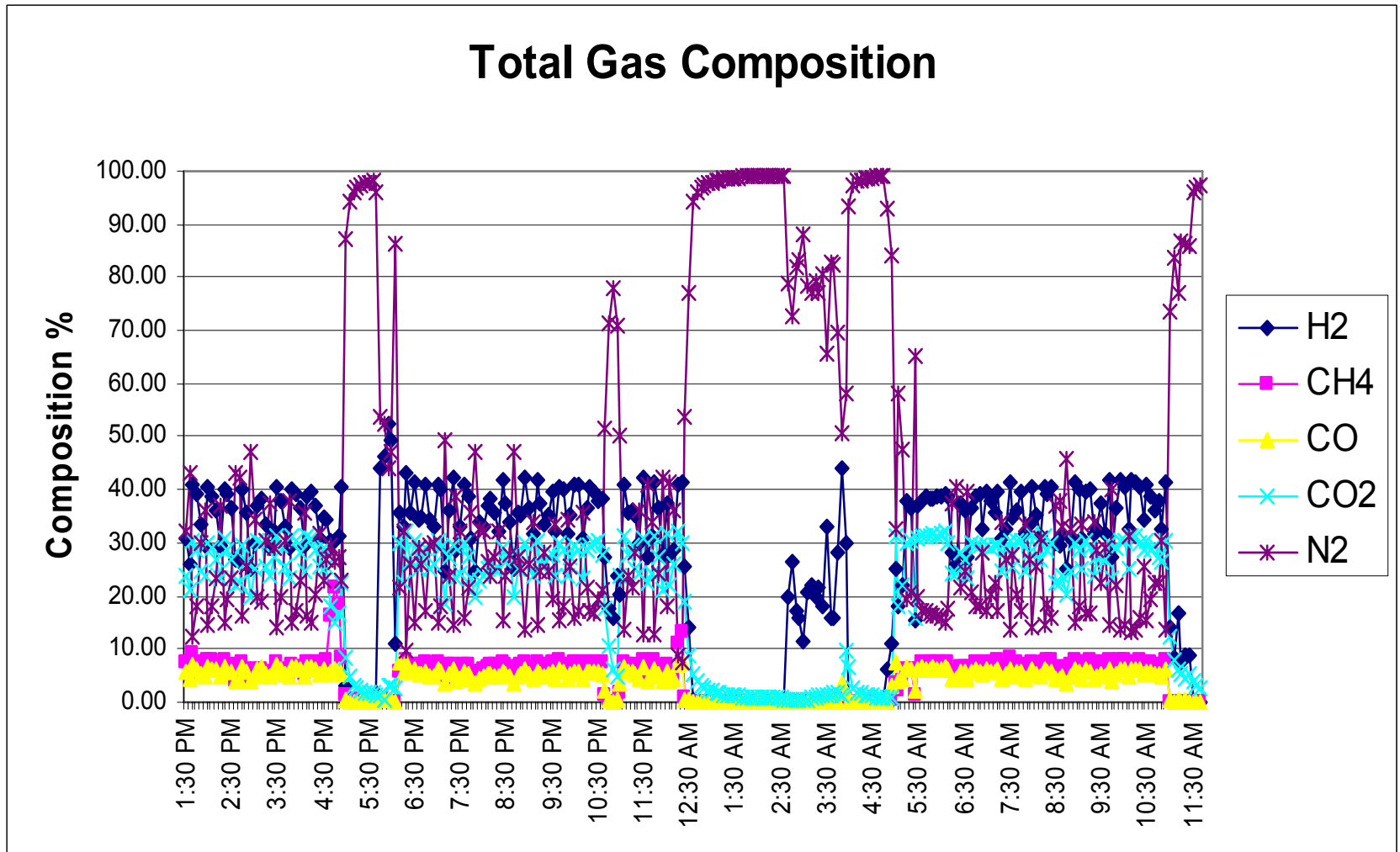
Catalyst Reduction Process



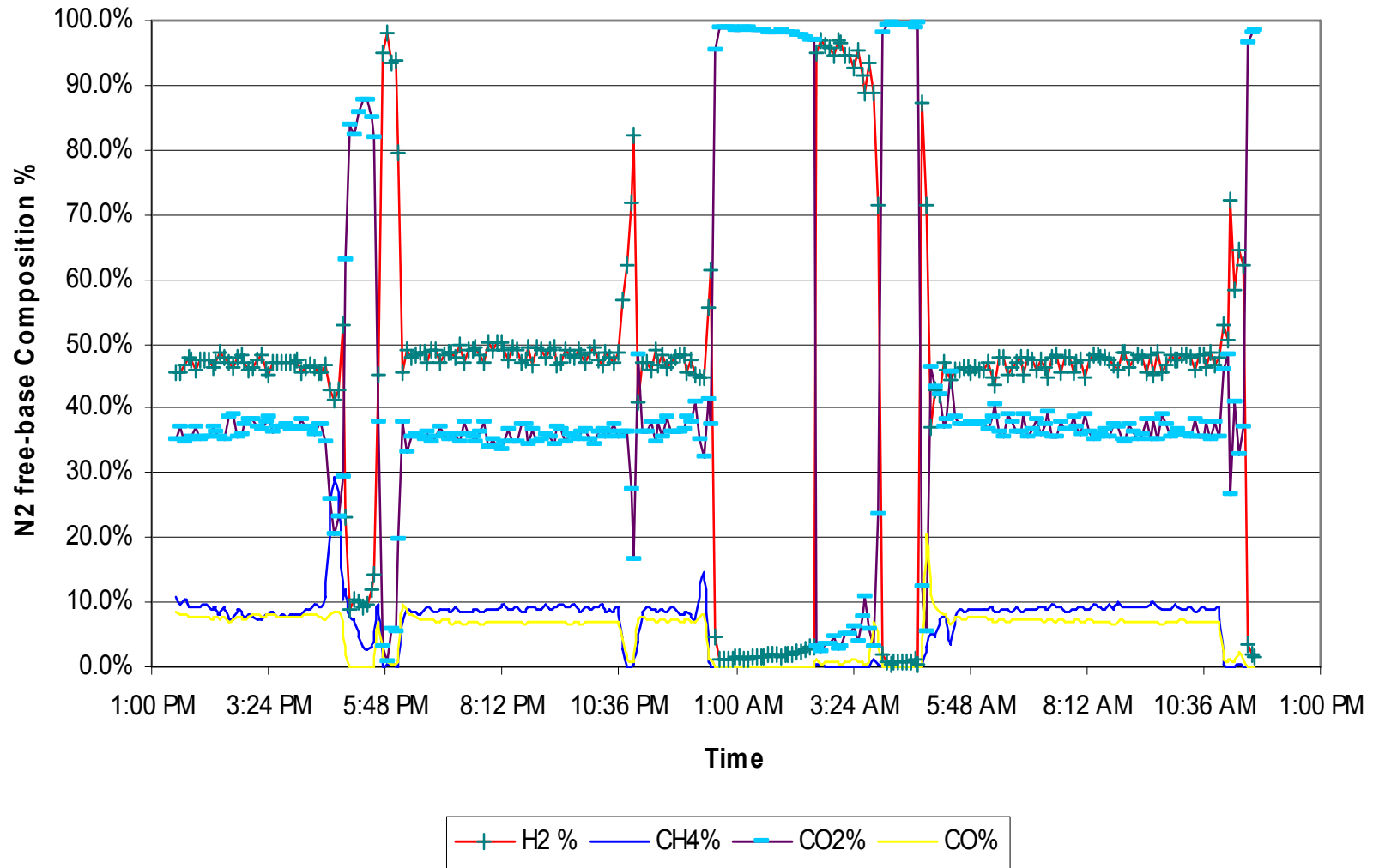
Photograph of Hydrogen Flame



Total Gas Composition vs Time (24 hrs)



Nitrogen free-Base Gas Composition vs Time (24hrs)



Typical Analysis of Peanut Shell Feedstock

• Component	%
– Lignin -----	34.8
– Glucan -----	21.1
– Extractives -----	14.2
– Protein -----	11.1
– Xylan -----	7.9
– Ash -----	3.4
– Arabinan -----	0.7
– Galactan -----	0.2
– Mannan -----	0.1
– Others (e.g., free carbohydrates) -----	6.5

TYPICAL PRODUCT COMPOSITION/ YIELDS

Pyrolyzer (Yields)		Reformer (Gas product composition, on dry N ₂ -free basis)	
Char	32%	Hydrogen	49%
Water	32%	Carbon Dioxide	36%
Bio-Oils	31%	Carbon Monoxide	9%
Gases	5%	Methane	8%

Pyrolysis Bio-Oil Product

- **Empirical Formula:** $\text{CH}_{1.9}\text{O}_{0.7}$
- **Water:** 15 – 25%
- **Organics:** 75 – 85%
 - Aldehydes, alcohols and acids from carbohydrate fraction
 - Phenolics from lignin fraction
- **Representative Compounds**

Water

Ethanol

Methanol

Cyclohexanol

Formic Acid

Acetic Acid

Glucose

Phenol

O-cresol

2-Butanone

Dodecanoic acid

Tannin

ACCOMPLISHMENTS

- **Completed design, construction and testing of reformer (Phase 1)**
- **Completed integration of reformer with pyrolyzer (Phase 2)**
- **Completed 100 hours of successful operation of pilot unit (Phase 2)**
- **Completed modifications for 1,000 hours operation**
- **Completed 24 hours catalyst and process testing**
- **Identified potential co-products options**
- **Developed partnership and collaboration with potential companies/organizations**
- **Trained students**

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- **Partners**
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 - National Renewable Energy Laboratory, CO
 - University of Georgia, Athens