
Fuel-Flexible, Fuel-Processing Subsystem Development

Richard Woods

Hydrogen Burner Technology

3925 Vernon Street

Long Beach, Ca 90815

phone 562-597-2442 fax 562-597-8780

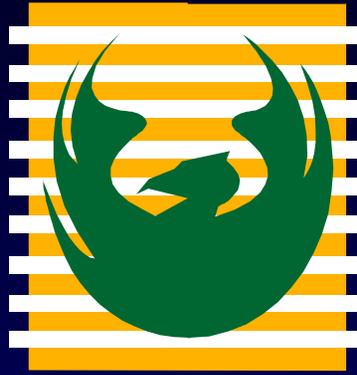


Phoenix Family of Companies



Phoenix Gas Systems

Industrial
Hydrogen
Generation



**PHOENIX
FUEL CELL
SYSTEMS**

Reformers
for Fuel Cell
Systems

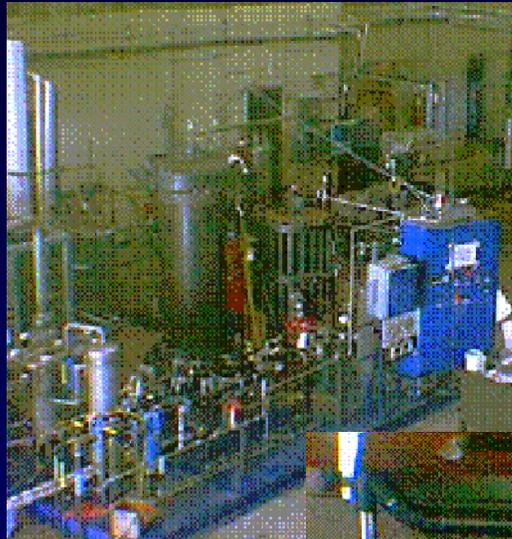


**PHOENIX
COMBUSTION
SYSTEMS**

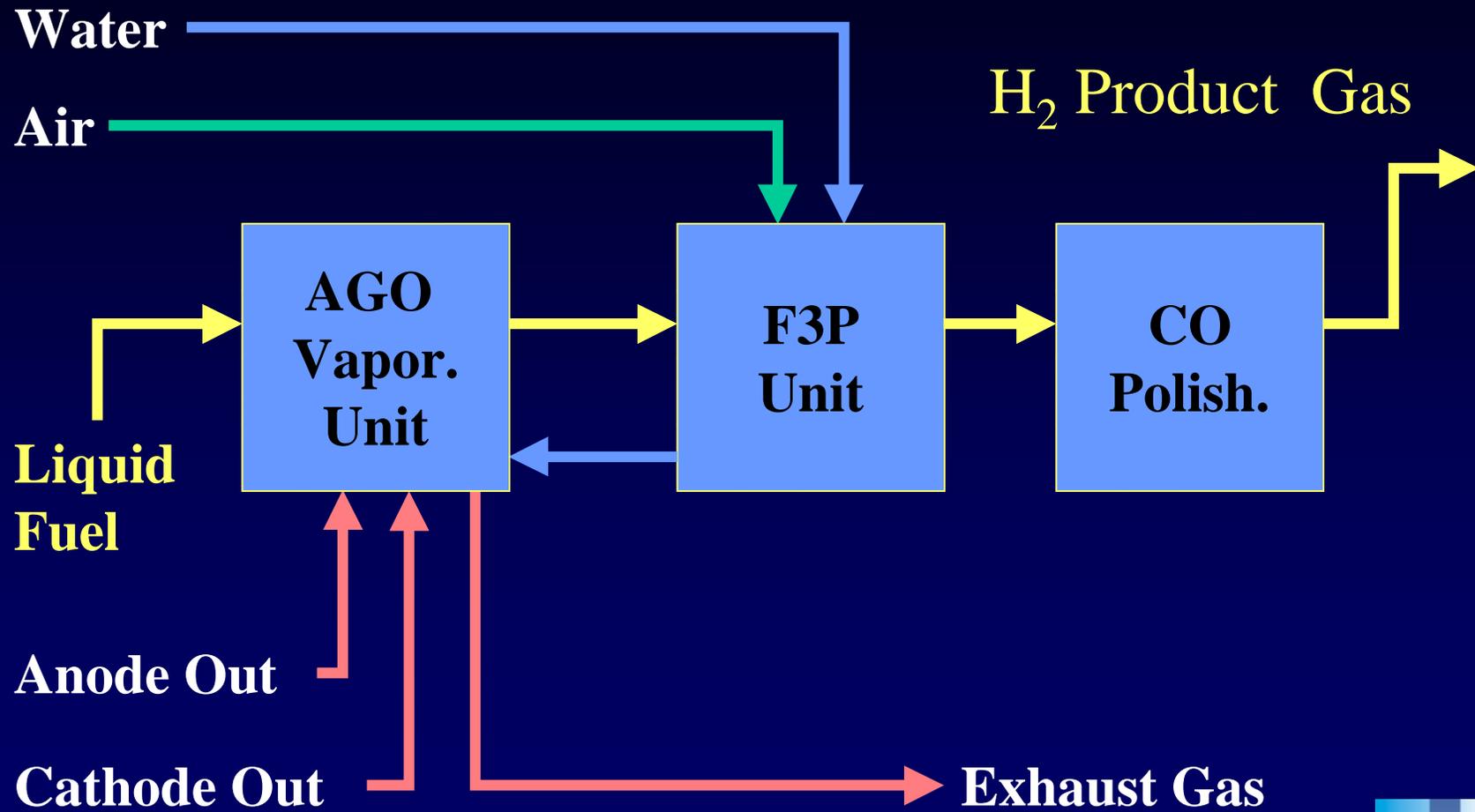
Combustion
Equipment

HBT's Long Beach Facility

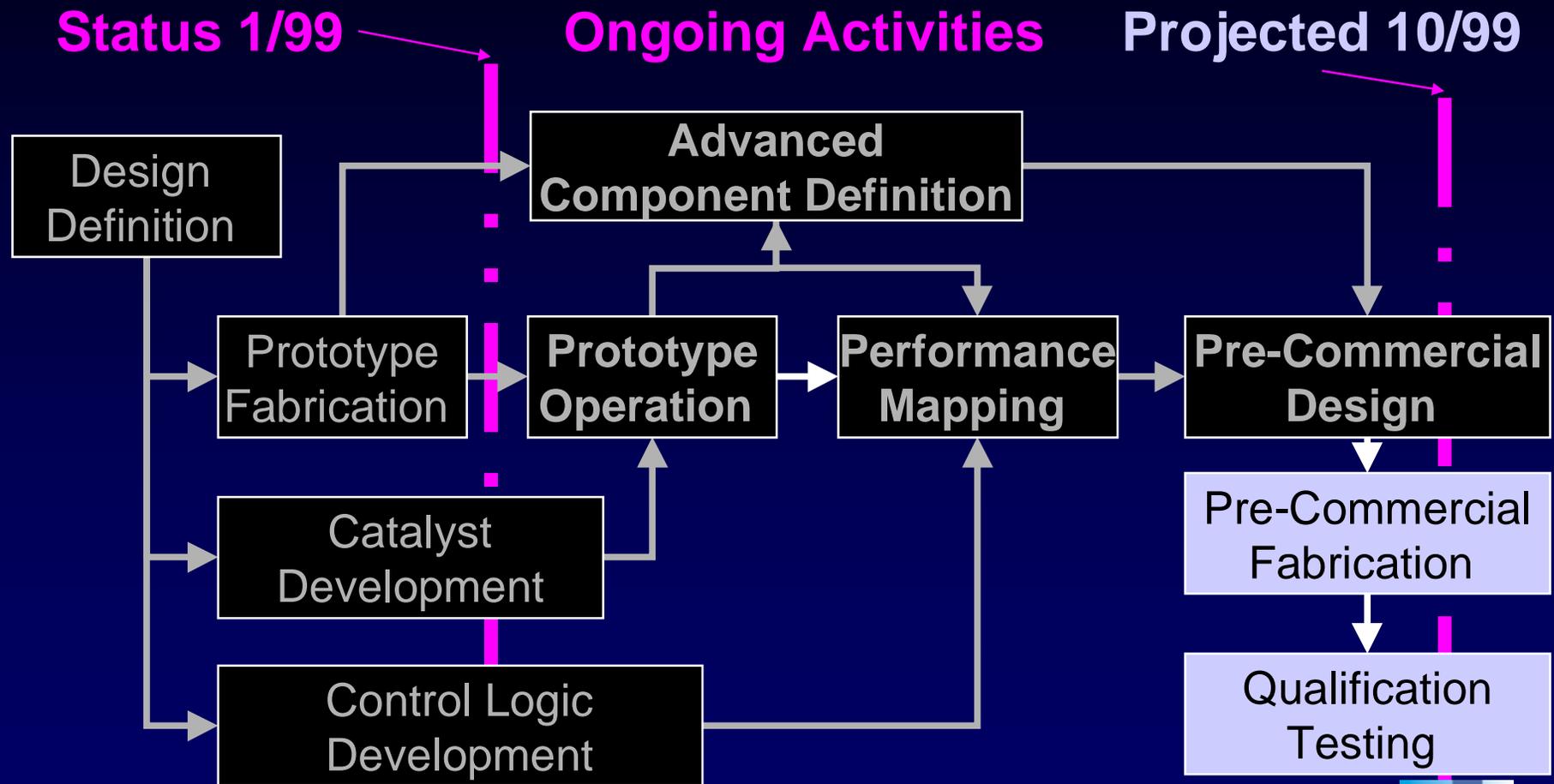
- Floor Space
 - 16,000 ft²
 - 1/3 Office
 - 2/3 Mfg
- Staffing
 - 35 people
 - 1/2 HBT
 - 1/2 PGS



F³P Subsystem

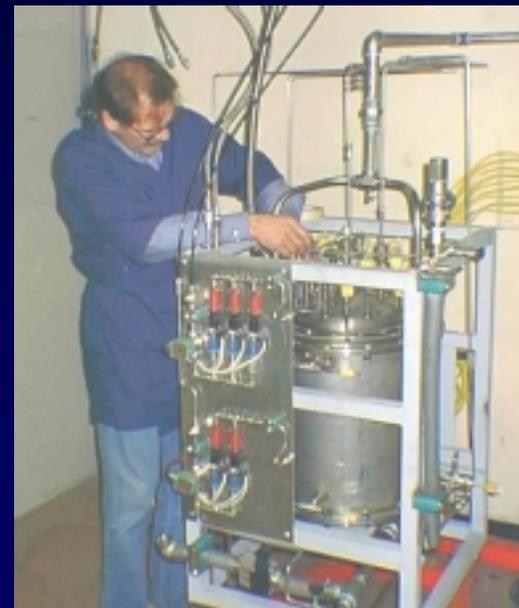


Program Scope Overview



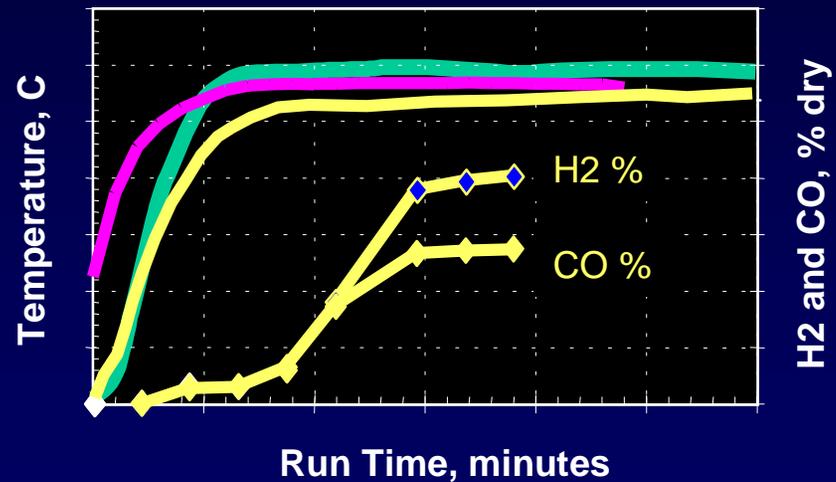
Accomplishments To Date

- Hardware Fabrication
 - Three Prototypes Delivered
 - Three Additional Prototypes in Construction



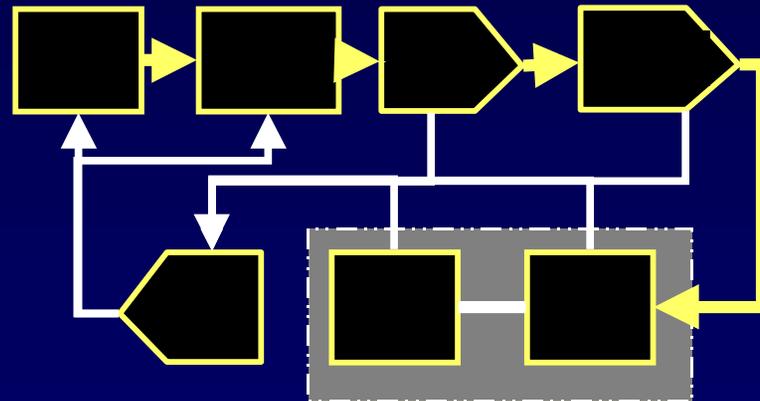
Accomplishments To Date

- Hardware Fabrication
- Operational Experience Over 120Hours
 - Gasoline
 - Pipeline Gas
 - Methanol



Accomplishments To Date

- Hardware Fabrication
- Operational Experience Over 100Hours
- Software Development
 - Manual Operation Implemented
 - Process PID Loops Developed



Accomplishments To Date

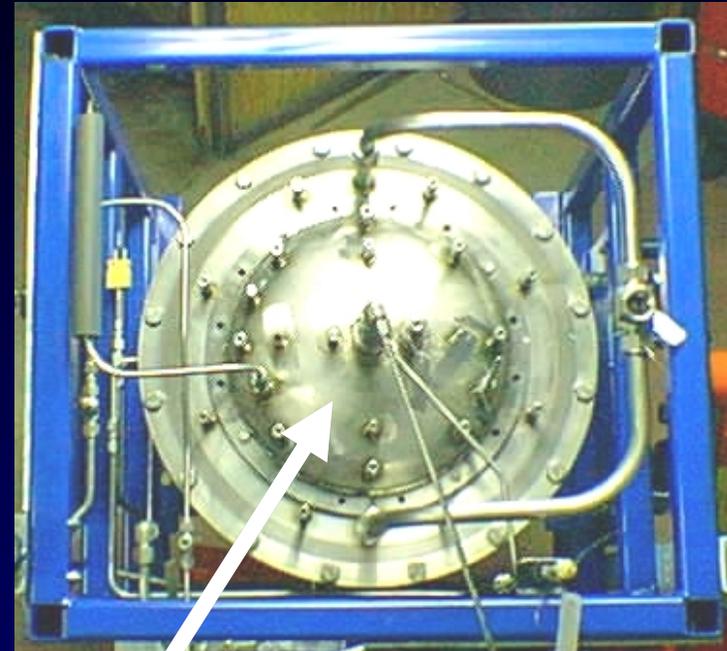
- Hardware Fabrication
- Operational Experience Over 100Hours
- Software Development
- Catalyst Developments
 - Three Advanced Shift Catalyst Tested
 - Autothermal Reform Catalyst Tested



Prototype F3P Assembly Configuration

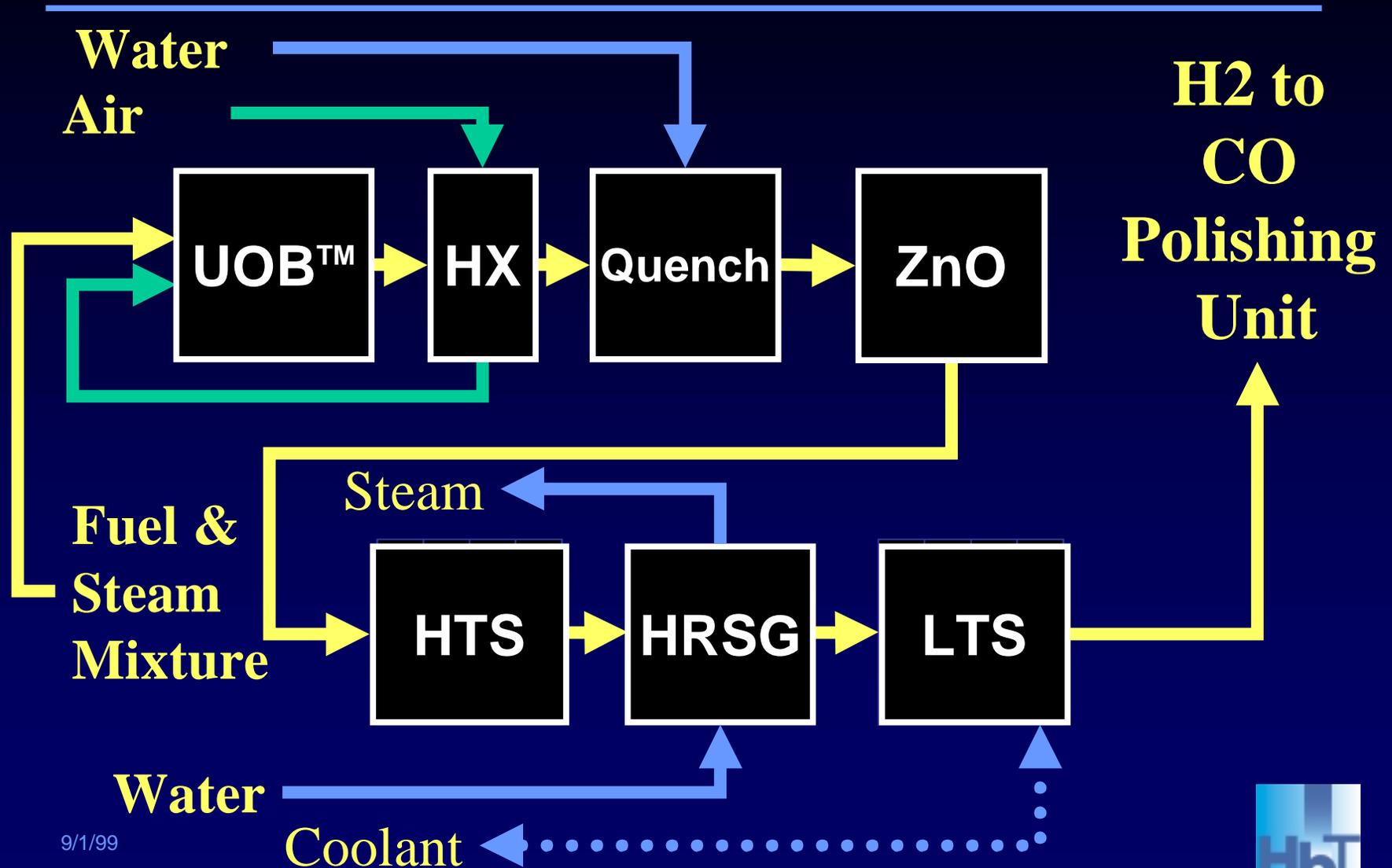


Prototype summary
- 230 LB at 38kW Demo.
- 350W/kg Verified



Top View with Test Frame
Side View with Test Frame

Integrated F³P Assembly

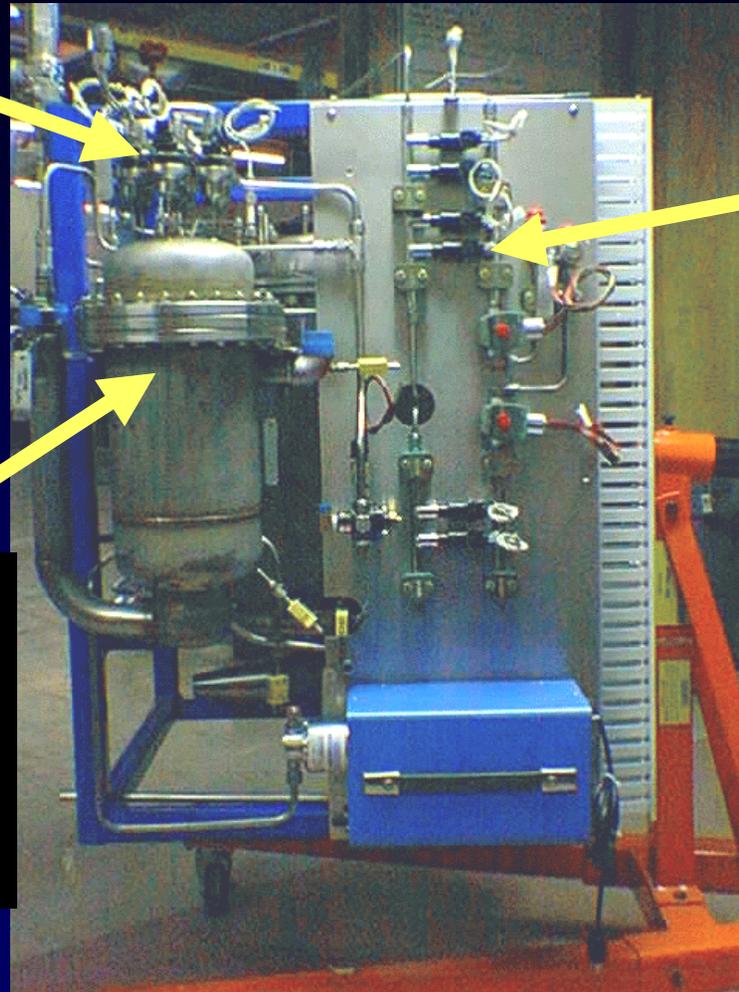


Hardware Fabrication

- One Set of 3 F3P Subsystems Completed
 - DOE/HBT Prototype (12/98)
 - Automotive Manufacturer (3/99)
 - LANL Prototype (5/99)
- Second Set of 3 F3P Subsystems in Process
 - Fuel Cell Integrator A (POX) (8/99)
 - Fuel Cell Integrator A (Autothermal) (10/99)
 - Fuel Cell Integrator B (11/99)
- Third Set of F3P Subsystems on Order
 - DARPA Project (1 units) (TBD)
 - CECERT (1 units) (12/99)
 - DOE Pre-Commercial (1 unit) (12/99)

Simplified Control Concepts

Digital
Fuel Control
Valves



Low Cost
Pulse Width
Modulating
Water Flow
Control
Valves

Integrated
Anode-Off
Gas Oxidizer
and Vaporizer

Operating Experience Summary

	S/N 001	S/N 002	S/N 003	S/N 004
Customer	HBT DOE	Auto MFG	LANL	FC Devel.
Fabrication	12/30/99	2/20/99	3/9/99	7/1/99
Delivered	1/1/99	3/5/99	5/28/99	TBD
Runs	26	11	13	11
Operating	36 Hrs	18 Hrs	24 hrs	46 hrs
Fuels	NG, Gasoline	NG, Gasoline	NG, Gasoline, Methanol	NG

9/1/99



Fuel Flexibility Comparison

Fuel Type	Target, % dry	Status, % dry
– Methanol	– > 40%	– 40%
– Ethanol	– ~ 40%	– Not Tested
– Natural Gas	– ~ 35%	– 33% (45%)
– Gasoline	– ~ 35%	– 31%
– Kerosene	– ~ 35%	– Not Tested
– Diesel	– ~ 33%	– Not Tested

Summary Verification Status

	Methanol	Nat. Gas	Gasoline
Minimum SR	0.33	0.40	0.42 - 0.45
Efficiency	<76%	~70%	~68%
Max H ₂ , %dry	40%	33%	30%
Min CO, (LTS only)	0.3 to 0.1%	0.4 to 0.1%	0.5 to 0.1%
Max Capacity, kWe***	38kWe	25kWe	20kWe

* Note preliminary performance based on ~ 100 hrs operation.

*** Estimated Capacity based on Fuel Consumption and H₂ Concentration.



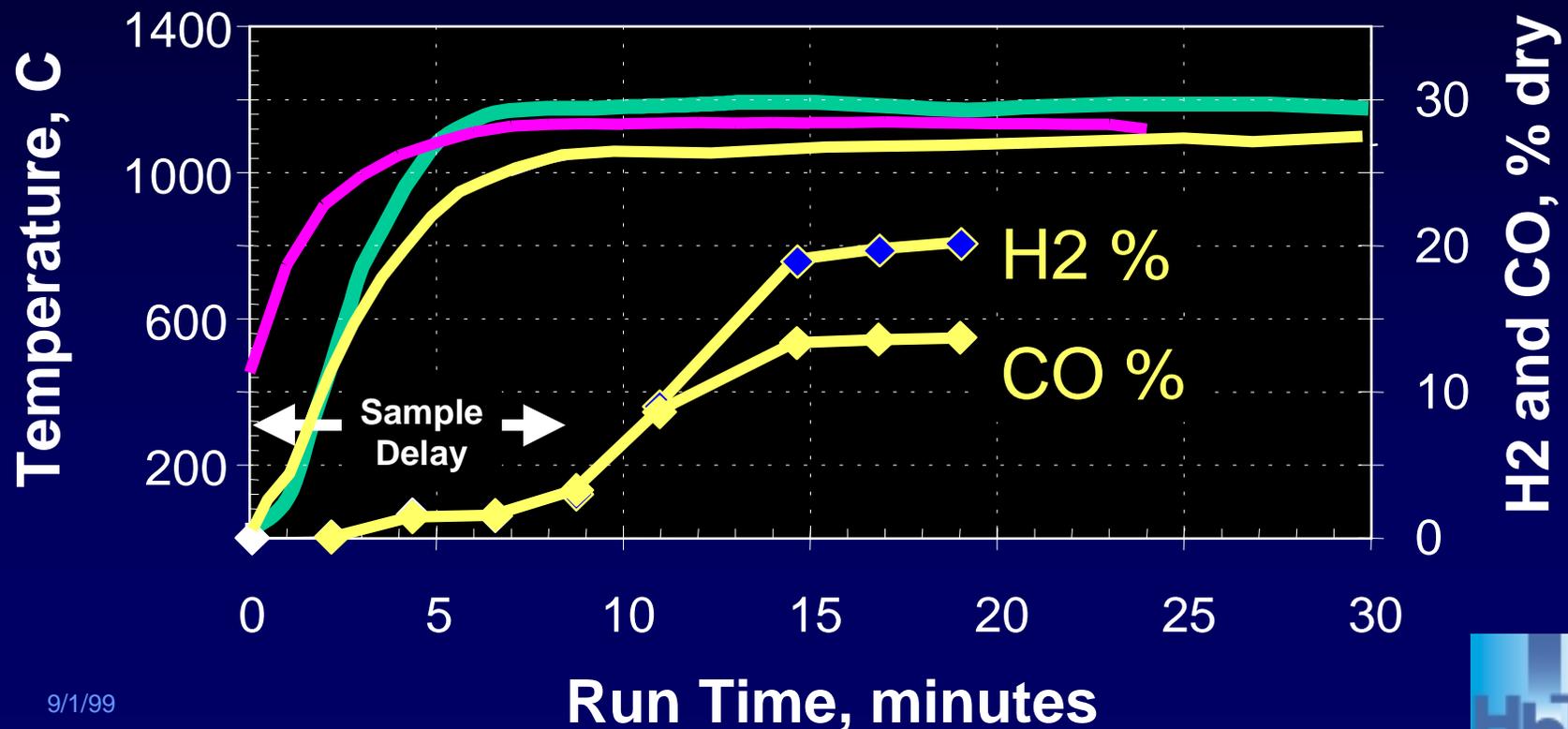
UOB™ Start Up Characteristics

UOB™ Reactor Temperatures

High Flow Start

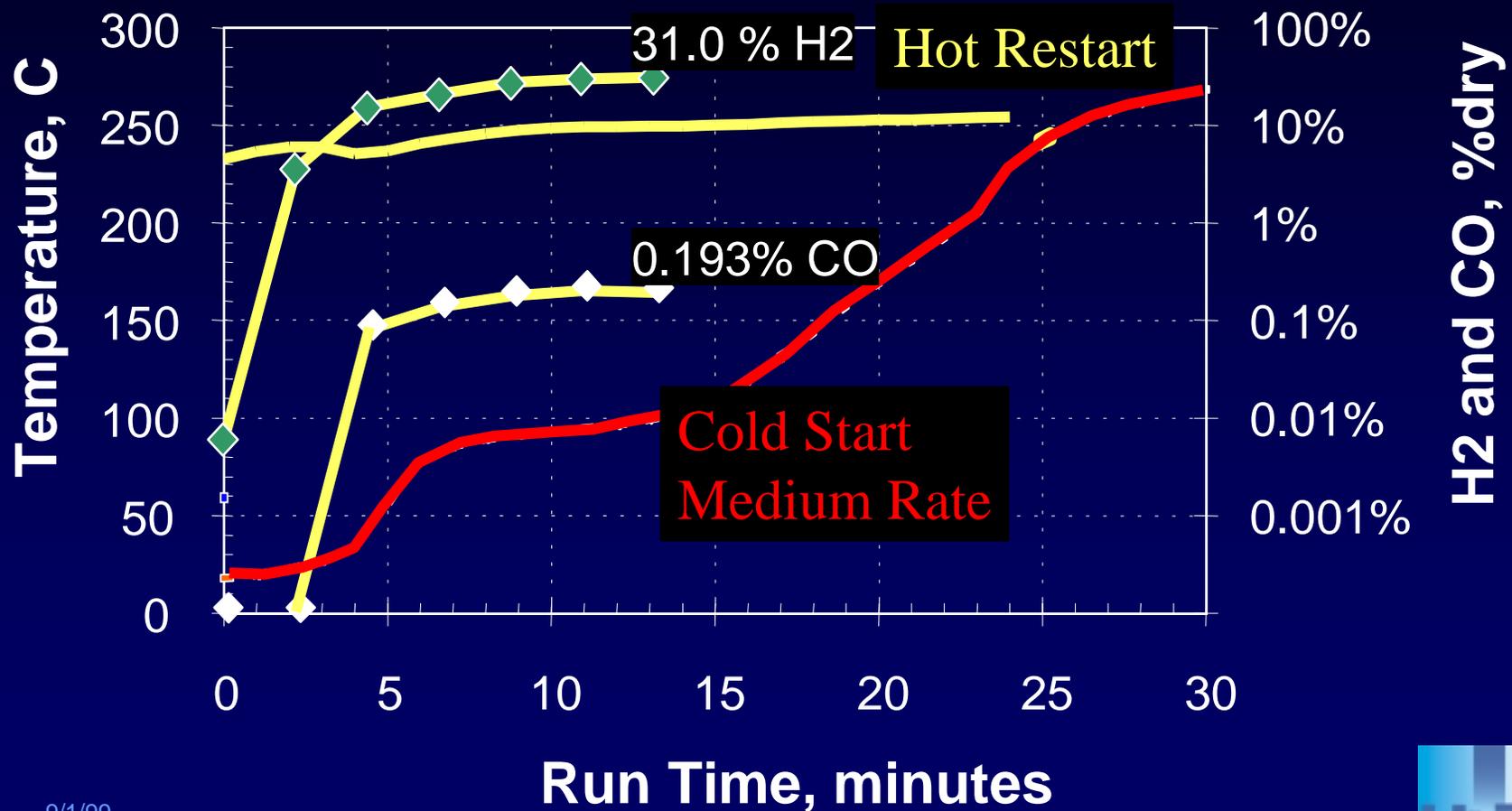
Hot Restart Start

Low Flow Start



Comparison of Start-Up Tests

Average LTS Temperatures



CO Polishing Testing

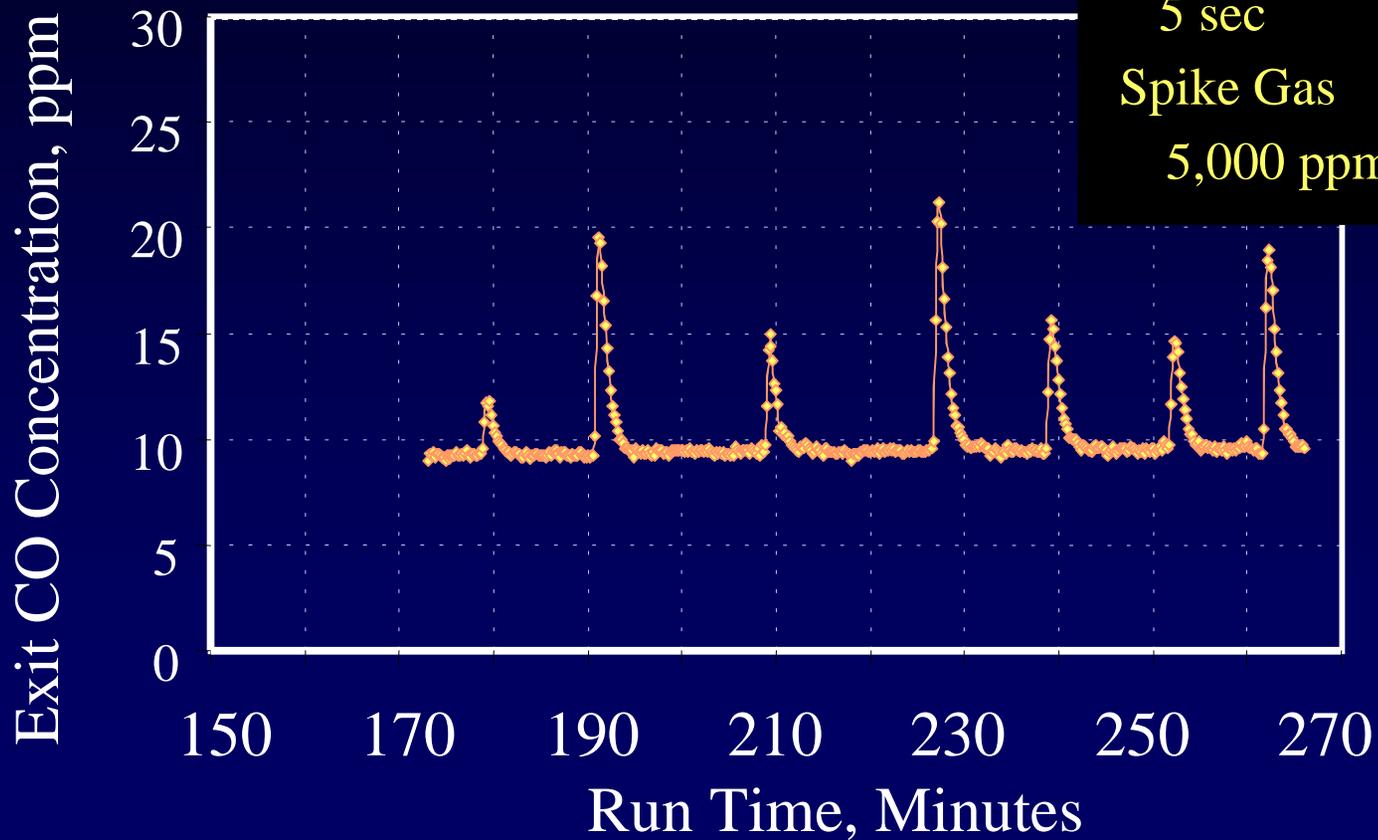


- Three Hardware Concepts Being Evaluated
- Preliminary Testing Conducted on Methanation
- PROX Reactor to be Tested in September 99

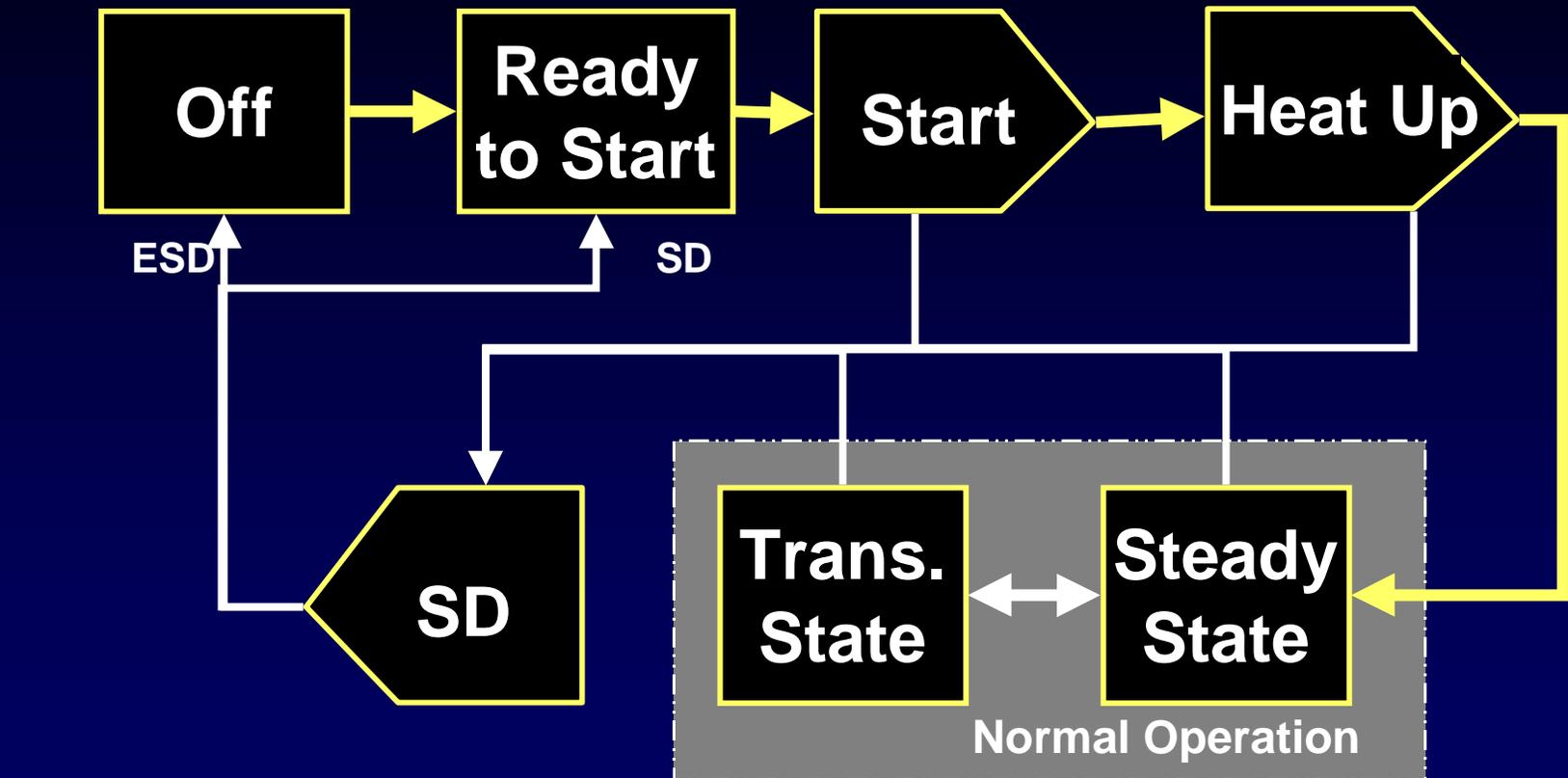
Methanation Response to Spike

Institute of Gas Technology Results

Spike Duration
5 sec
Spike Gas
5,000 ppm CO



Automatic Control Logic Structure



Continuous Stage Temporary Stage Transition Between Stages

Control Interface Screens

F3P Assembly - Process Flow Control

085:11 Automatic Semi-Auto

Start up Control

Start up Air (SOV025) **CLOSED** Start up Fuel (SOV087) **CLOSED**

PAFR — Process Capacity Control

Mass Flow Rate Control

Valve Position Control

PFFR — Process Reactor Temperature

Reactor Temperature °F

Setpoint °F

Low S.R.High Setpoint lbs/hr

Valve Output % DC

UOB Igniter **F3P IGNITION On/Off**

DATA LOG Alarm Box EMO ENABLE STOP

Intro
Check List
Start Up
Parameter
Operation
Capacity
Vaporizer
Reactor
Quench
LTS
SD Logs
Polisher

- Two Control Modes
 - Automatic
 - Semi-Automatic

Control Interface Screens

F3P Assembly - Process Flow Control

Automatic Semi-Auto

Start up Control

Start up Air (SOV025) **CLOSED** Start up Fuel (SOV087) **CLOSED**

PAFR Process Air Flow Rate

Capacity Control Setpoint %

0.0% 1

Mass Flow Rate Control (FT008) Setpoint

0.0 lbs/hr 1.1 lbs/hr

Valve Position Control (CV010) Valve Output

0

PFFR Process Fuel Flow Rate

Reactor Temperature

0.0

Mass Flow Rate Control (FT008) Setpoint

0.0 lbs/hr

Valve Duty Cycle Control

0%

TT084 Air Preheat Temperature 0°F

TT085 Comb. Spark Temp 0°F

TT051 Fuel Mix Temperature 0°F

TT052 Comb. Exh. Temperature 0°F

TT001 Reaction Temperature 0°F

TT002 Reactor Out Temp. 0°F

TT003 HTS Inlet Temperature 0°F

TT004 LTS Inlet Temperature 0°F

Steam Temperature

Intro

Check List

Start Up

Parameter

Operation

Capacity

Vaporizer

TUNING LOG Box ENABLE STOP

Autothermal Reforming Catalyst



- Standard F3P Hardware Configuration
- Simple Modification
- Catalyst Provided by Engelhard Corporation
- Initial Testing
 - 10 runs & 20 Hrs
 - 42% to 50% H₂ Equivalent
 - CH₄ Slip 1-6% Range
- ATR Subsystem to be Delivered 10/99

Summary and Conclusions

- F3P Subsystem Development Effort
 - Established the Process Integration Issues and Opportunities
 - Verified On-Board Hardware Operational Characteristics
 - Evaluated Automotive Subsystem Needs and Criteria
 - Identified Advanced Concept Hardware and Packaging Approaches