Farmingdale State College

State University of New York

BROOKHAVEN NATIONAL LABORATORY

IRTT

Institute for Research and Technology Transfer

Center of Excellence for Green Energy Research

2010 FaST Program BNL and IRTT/FSC

PURE HYDROGEN FROM BIOMASS TO POWER A PEM FUEL CELL FOR CHP

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Research Objective

The main objectives of the current research work are:

1) **Develop an integrated system to produce ultra pure hydrogen**
2) **Test and evaluate the industrially available catalysts —FeCr and CuZn for Water Gas Shift (WGS) reaction**
3) **Future development of more efficient and safe catalyst**

To Solve our National Energy and Economic Problems - We have to reduce our dependence on Foreign Oil by Utilizing Renewable Energy and conserving energy

Renewable Sources of Energy are:

- **Wind**
- **Solar**
- **Geothermal**
- **Hydro**
- **Biomass**

What Is Biomass?

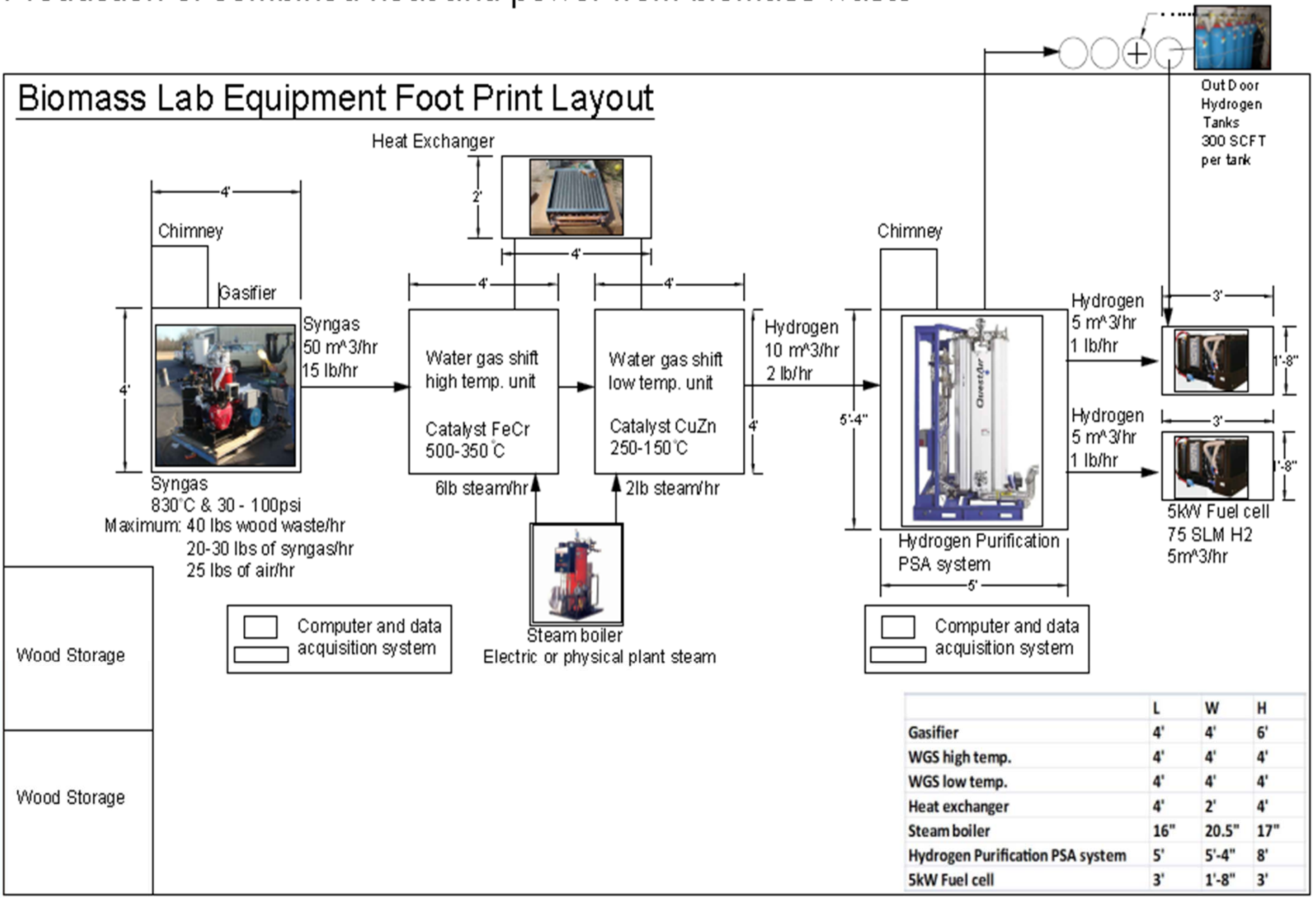
Biomass is a renewable organic resource, includes agriculture waste, such as corn husks or wheat straw; forest debris; and crops grown specifically for energy, such as switch grass or willow trees.

What is Gasification?

Gasification is heating biomass with about one-third of the oxygen necessary for complete combustion—produces a mixture of carbon monoxide and hydrogen, known as synthesis or syngas.

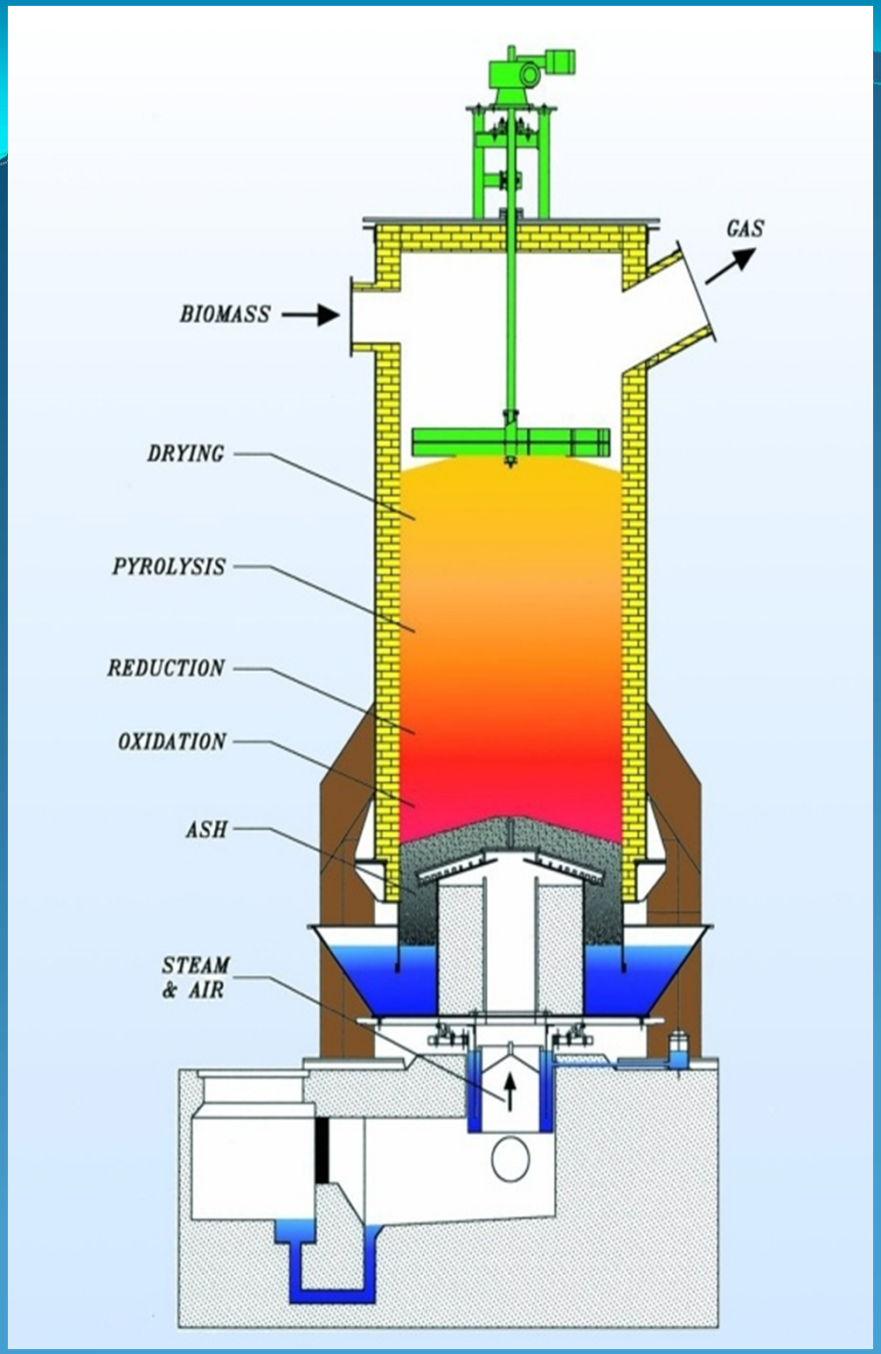
Biomass Project

Production of combined heat and power from biomass waste



	L	W	H
Gasifier	4'	4'	6'
WGS high temp.	4'	4'	4'
WGS low temp.	4'	4'	4'
Heat exchanger	4'	2'	4'
Steam boiler	16"	20.5"	17"
Hydrogen Purification PSA system	5'	5'-4"	8'
5kW Fuel cell	3'	1'-8"	3'

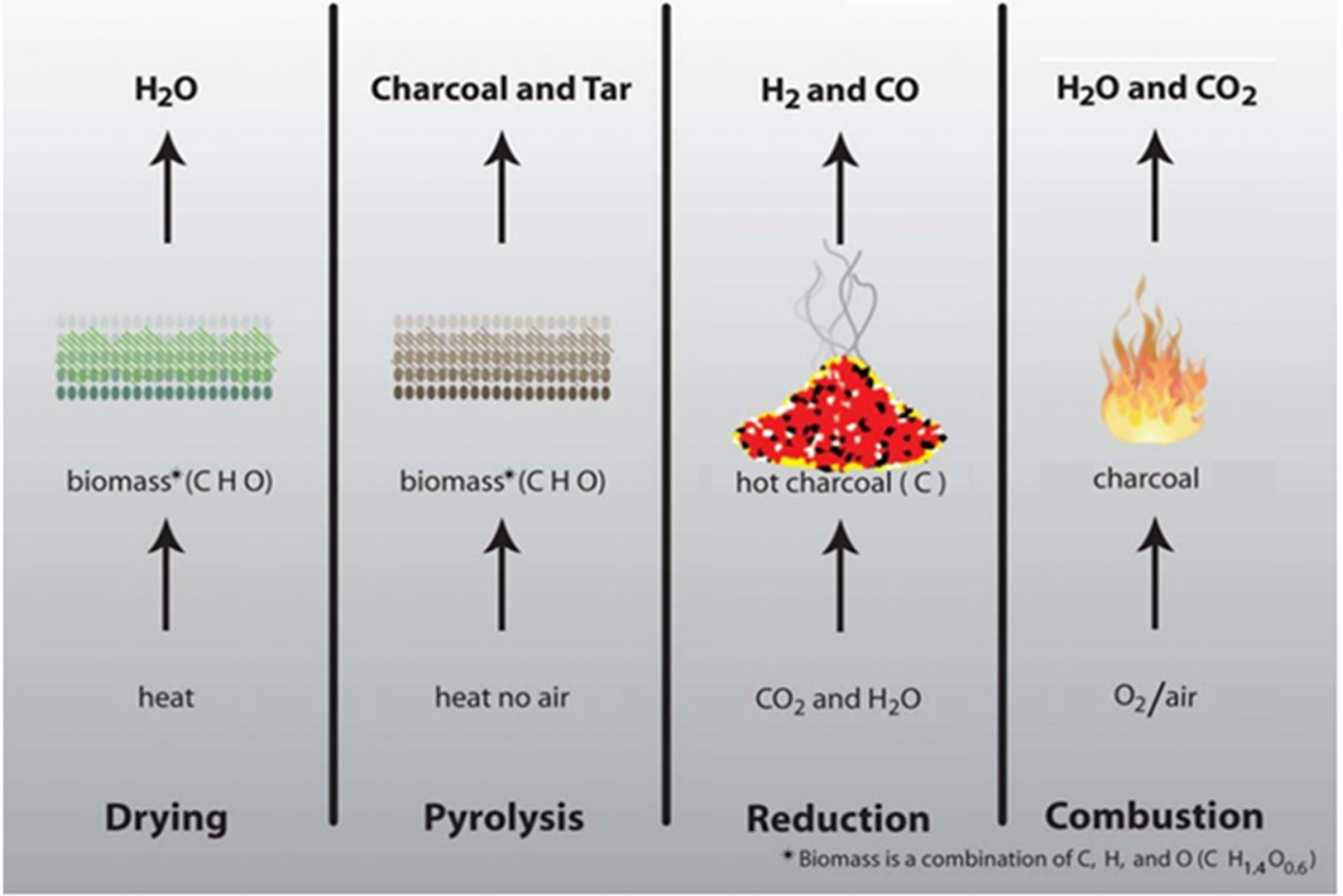
Wood Chips Palletizer – 1 kW Motor 40 lbs /hr



Farmingdale Gasifier

- Technical Specifications
- 10 kW
- Gasification fuel is wood chips with 15% water
- Syngas 50 m^3/hr or 15 lbs/hr
- Wood Chip up to 40 lbs /hr
- 10 -25 lbs of air per hr
- Efficiency 70%
- Foot print 4 x 4 feet – height 5.5 feet

4 Processes in Gasification



The Reduction Reactions

The Heart of Gasification

C
carbon

INPUT

$CO_2 + H_2O$
carbon dioxide + water vapor

Red Hot Charcoal Bed

OUTPUT

$H_2 + CO$
hydrogen + carbon monoxide

REACTIONS

$CO_2 + C = 2CO$
carbon dioxide + carbon = carbon monoxide

$H_2O + C = H_2 + CO$
water vapor + carbon = hydrogen + carbon monoxide

- Syngas which is a mixture of H_2, CO, CO_2 and H_2O (steam) must be followed by water gas shift (WGS) and CO clean-up steps

- The generation of high-purity hydrogen from Biomass for PEM fuel cell applications is essential for efficient & safe operation.

Syngas Composition

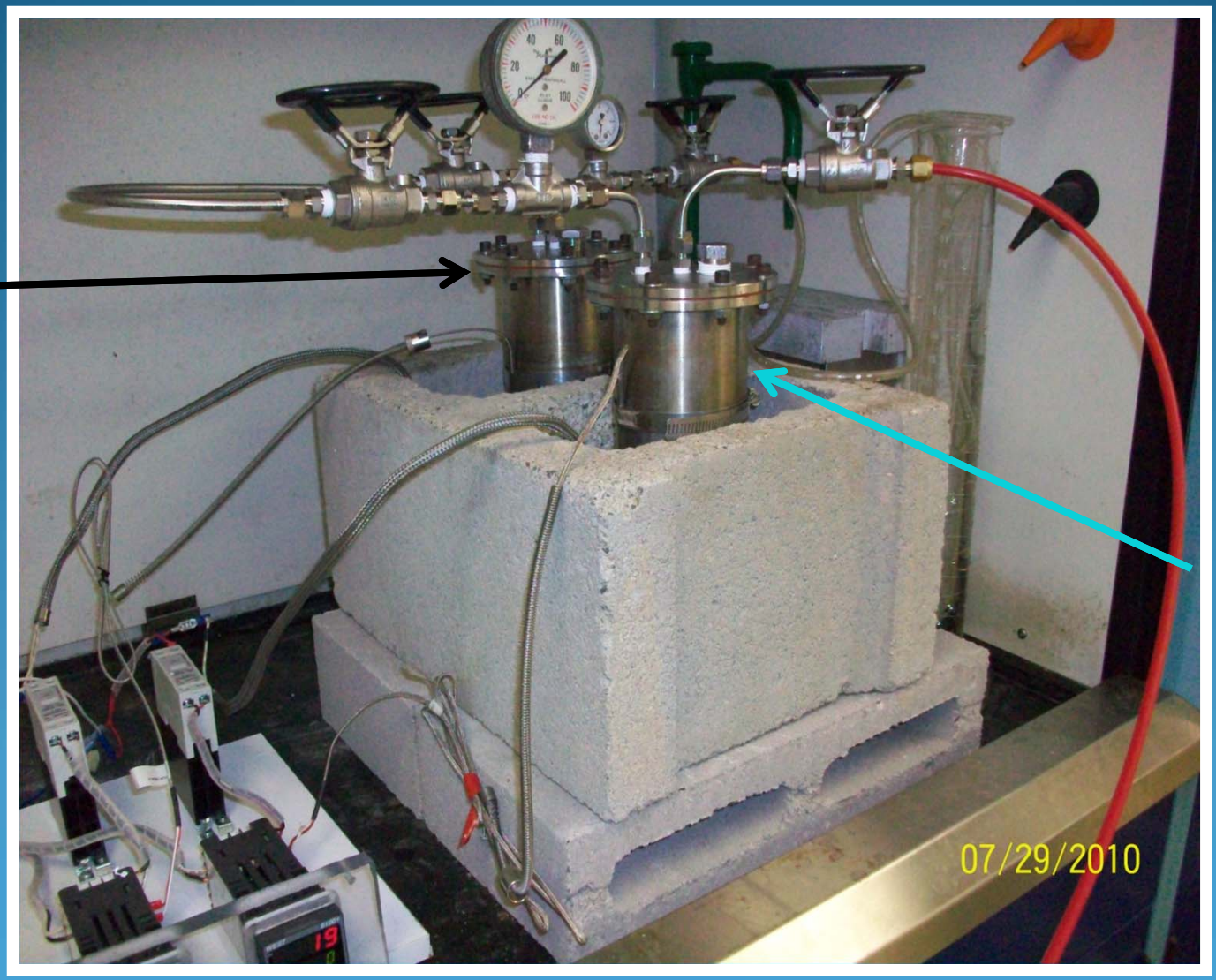
Component	Proportion
CO	20%
H_2	19%
CH_4	1%
CO_2	9%
N_2	51%
Tar	<80 ppm

Chemistry of Biomass Gasifier

- ***Simplified Example Reaction***
  $C_6H_{12}O_6 + O_2 + H_2O \rightarrow CO + CO_2 + H_2 +$ other species
  Note: ***Cellulose and Glucose are the major components of Biomass***.

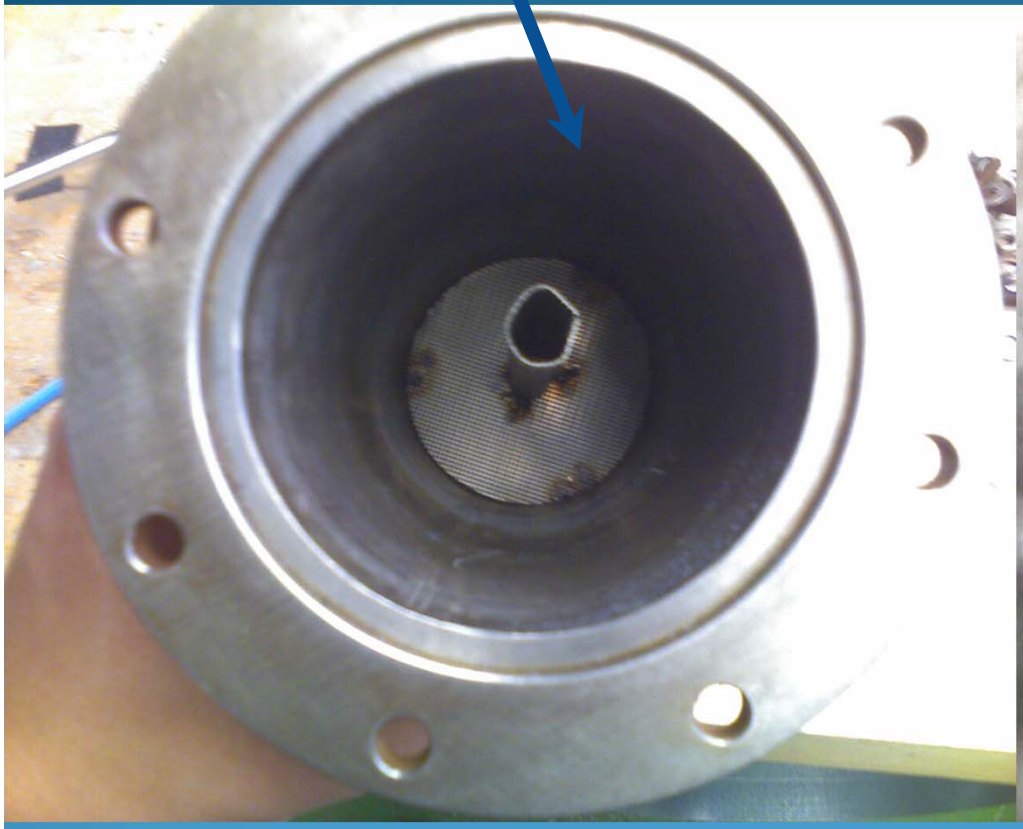
- ***Water-Gas Shift Reaction***
  $CO + H_2O \rightarrow CO_2 + H_2$ (+small amount of heat)

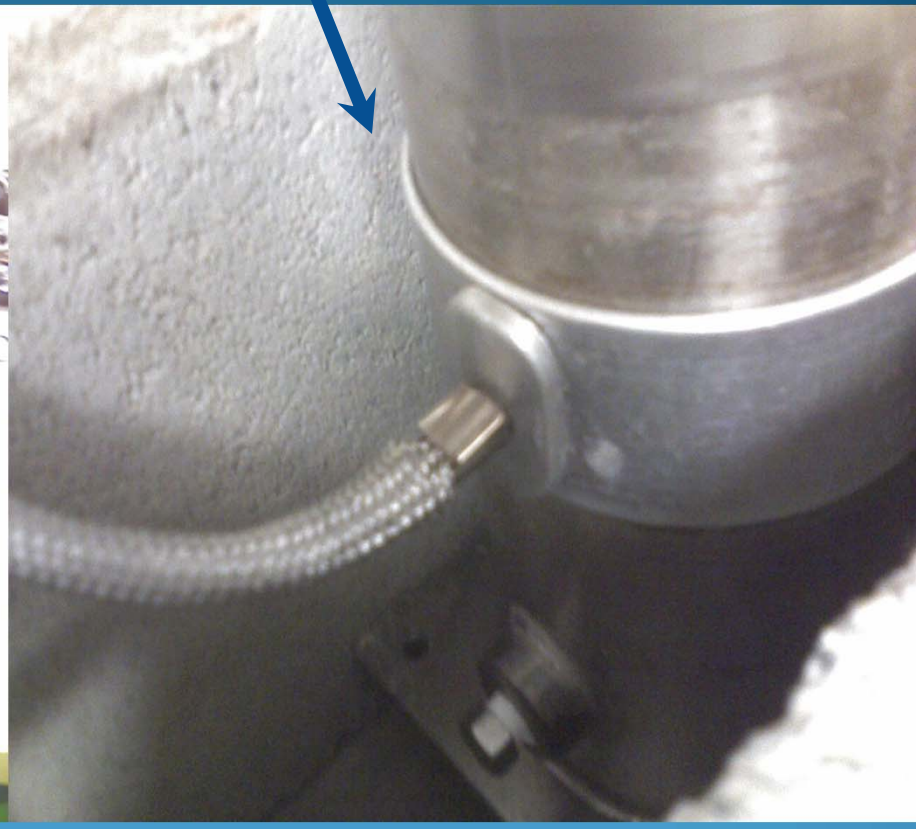
Catalyst Testing Reactors



Catalyst stainless steel screen support

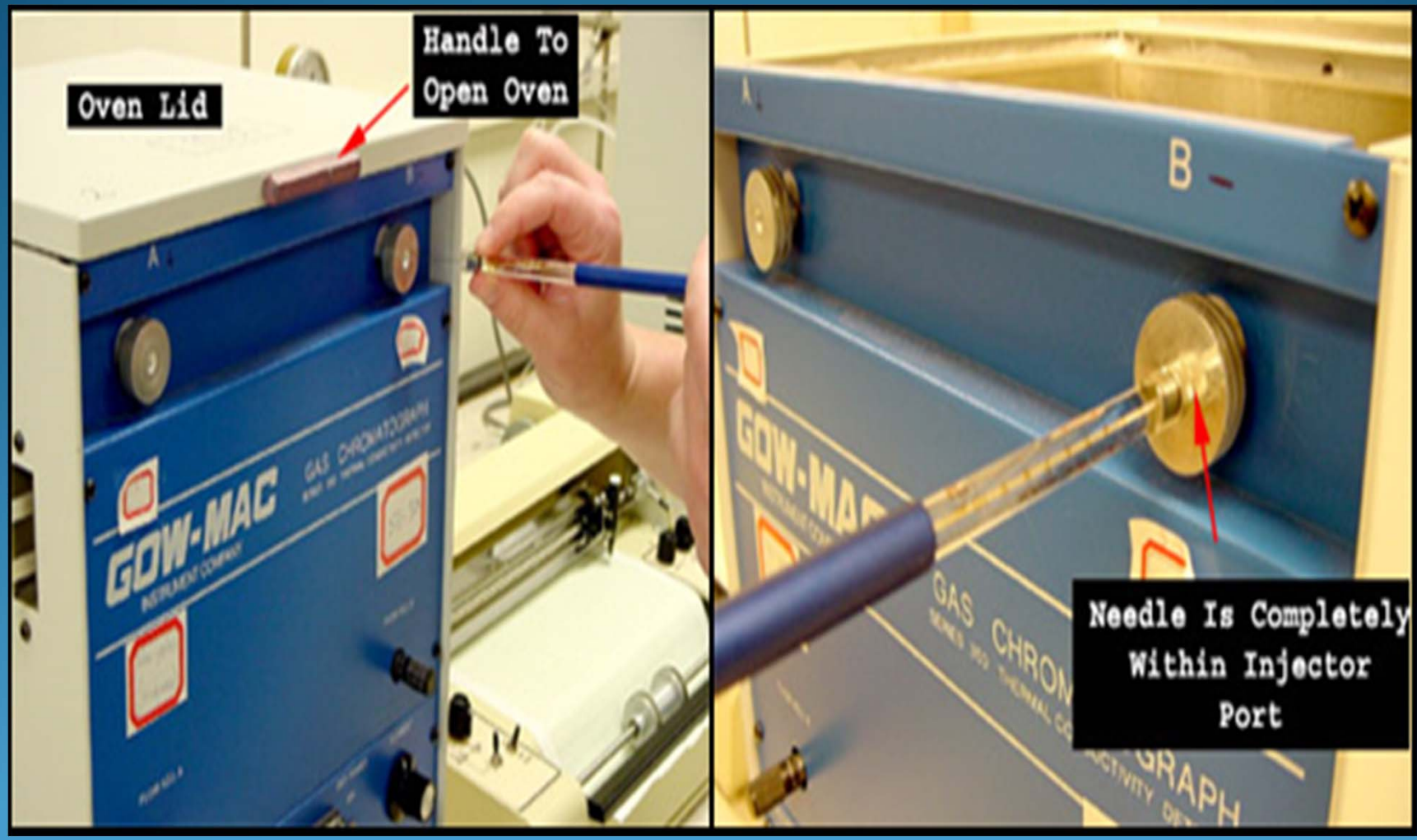
Electric Heater of the Shift Reactor





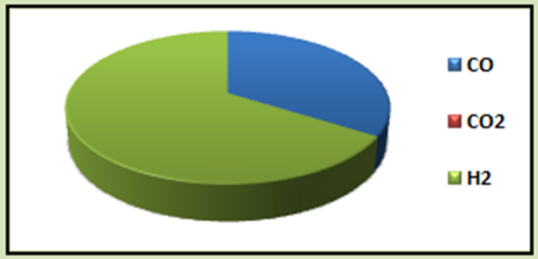
The industrial WGS reaction is carried out using two particulate catalysts—FeCr and CuZn—at temperatures between 320–500 and 120–250 °C, respectively.

Gas Mixture Samples Injected to GC

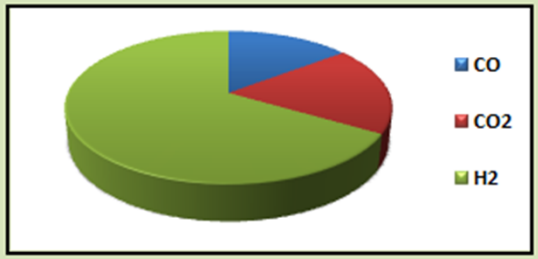


RESULTS

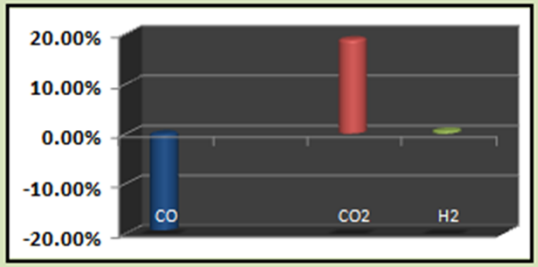
Initial Gases	
GAS	%
CO	33.94%
CO2	0.00%
H2	66.06%
TOTAL	100.00%



Final Gases	
GAS	%
CO	14.60%
CO2	18.85%
H2	66.55%
TOTAL	100.00%



Change	
GAS	%
CO	-19.34%
CO2	18.85%
H2	0.49%



CONCLUSIONS

- **The Low Temperature shift catalysts (CuZn) has reduced the amount of CO present in the syngas.**
- **The High Temperature shift(320-500) catalysts (FeCr) is expected to reduce the CO to < 10 ppm**

Future Work

- Both catalysts are pyrophoric: they spontaneously generate heat at high temperatures when exposed to air after activation – alternative catalysts will be explored

- Low-temperature water-gas shift reaction over Cu- and Ni-loaded cerium oxide catalysts - Will be investigated as an alternative

Hydrogen Purification Techniques

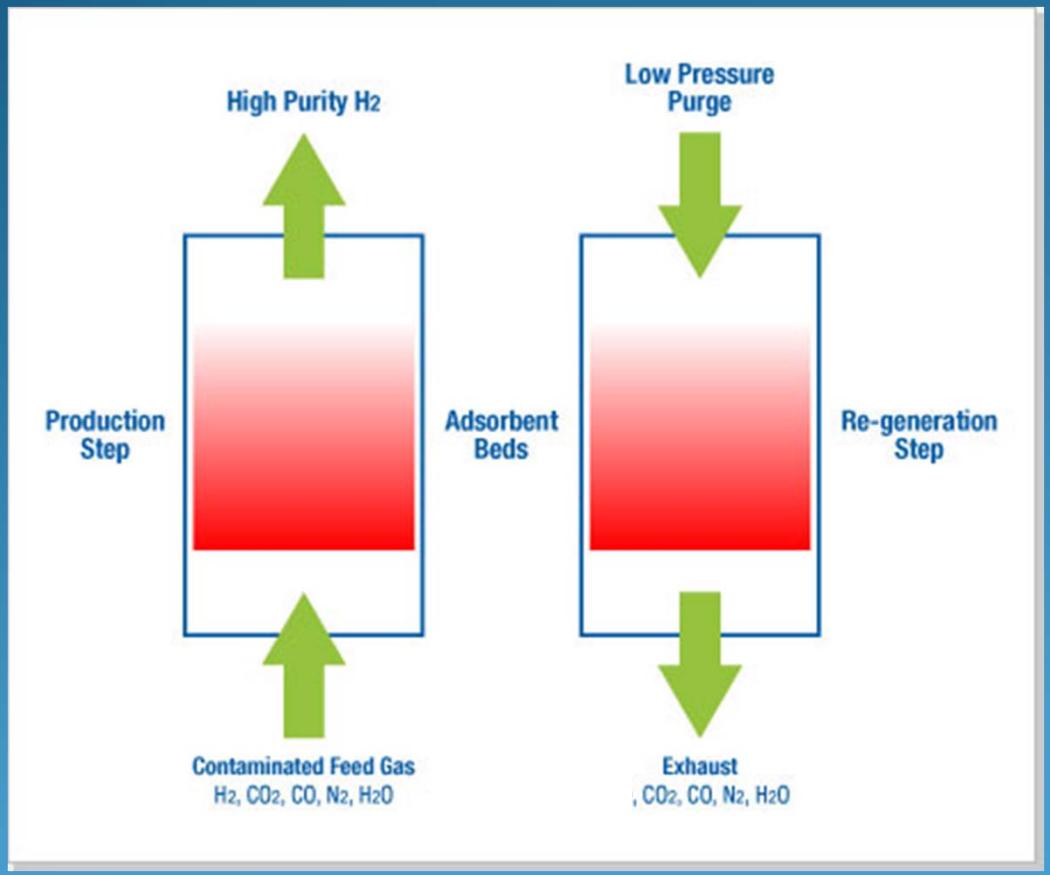
- **Absorbers - Pressure Swing Adsorber(PSA)**
- **Special membranes can separate hydrogen from the gas stream**
- **Partial Oxidation**

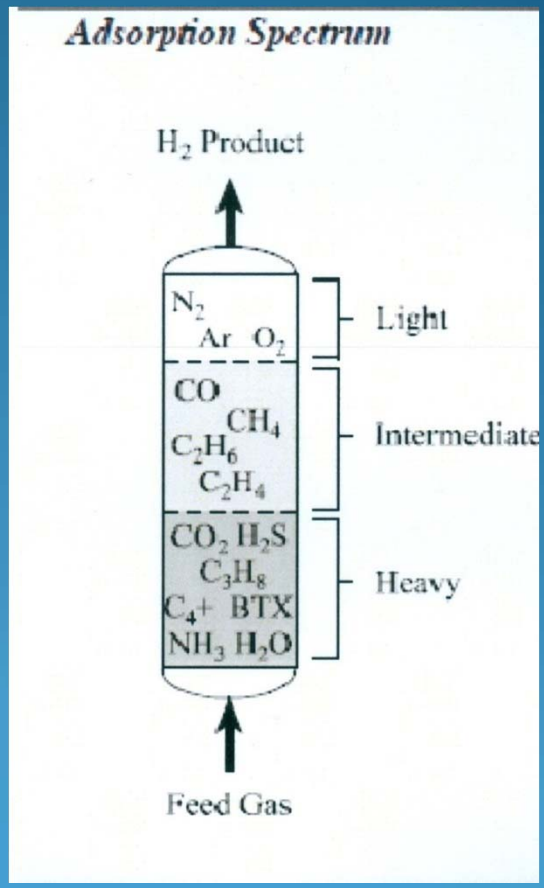
Hydrogen Purification Unit

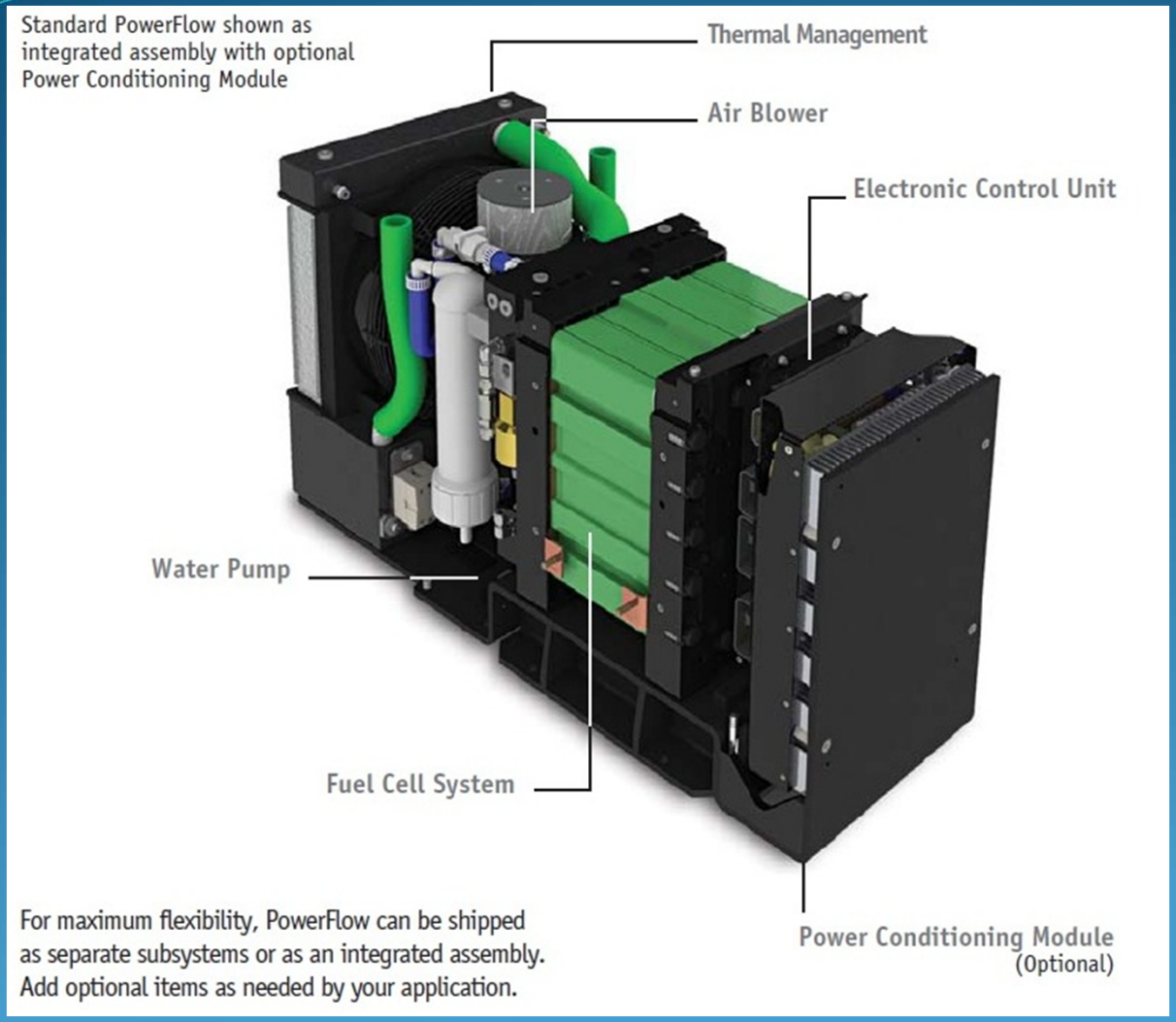
QuestAir™ H-3200

Hydrogen Purification PSA Systems

Height: **240 centimeters**
Width: **160 centimeters**
Depth: **150 centimeters**
Input(s):
Input range: **5 Nm3/hr min. - 300 Nm3/hr max.**
Output type: **hydrogen**
Output amount: **5 to 300 Nm3/hr**
Efficiency: **80+%**
Maintenance: **Annual Check**
Runtime: **10 to 15 years**


High Purity H2
Low Pressure Purge
Production Step
Adsorbent Beds
Re-generation Step
Contaminated Feed Gas
H2, CO2, CO, N2, H2O
Exhaust
, CO2, CO, N2, H2O


Adsorption Spectrum
H2 Product
N2
Ar O2
Light
CO
CH4
C2H6
C2H4
Intermediate
CO2 H2S
C3H8
C4+ BTX
NH3 H2O
Heavy
Feed Gas



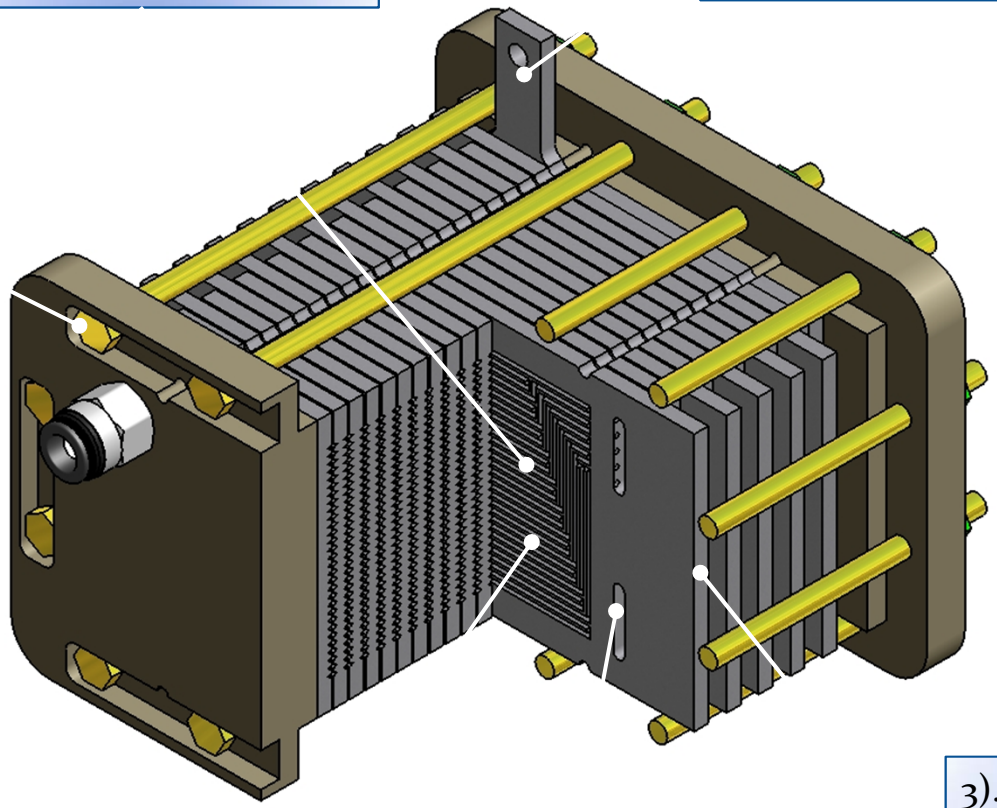
Fuel Cell consumption 5 m3 or 1 lb Hydrogen per hour

IRTT/Farmingdale PEM Fuel Cell

1). Low Contact Resistance & High Corrosion Resistance Coating

2). Integrated Terminal Design

6). Tightening Bolt Locking Design



Fuel Cell consumption 5 m3 or 1 lb Hydrogen per hour

3). Integrated Cooling Design (Fins) 2006, 2007 & 2008 FaST program

4). Improved serpentine Design 2007 FaST program

5). Internal Manifold Design