Ultra Clean Hydrogen From Biomass to Generate Combined Heat and Power using Fuel Cells

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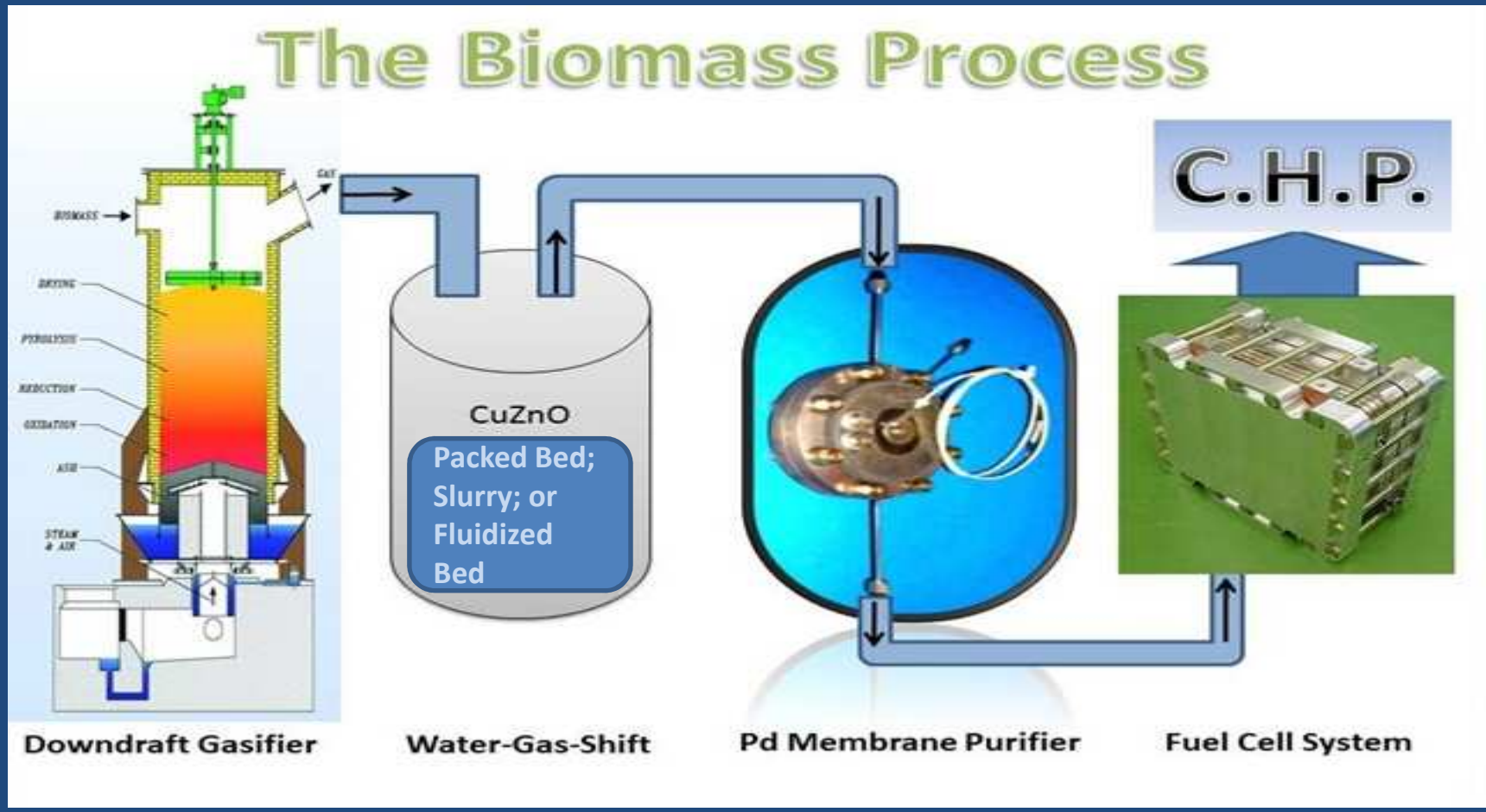
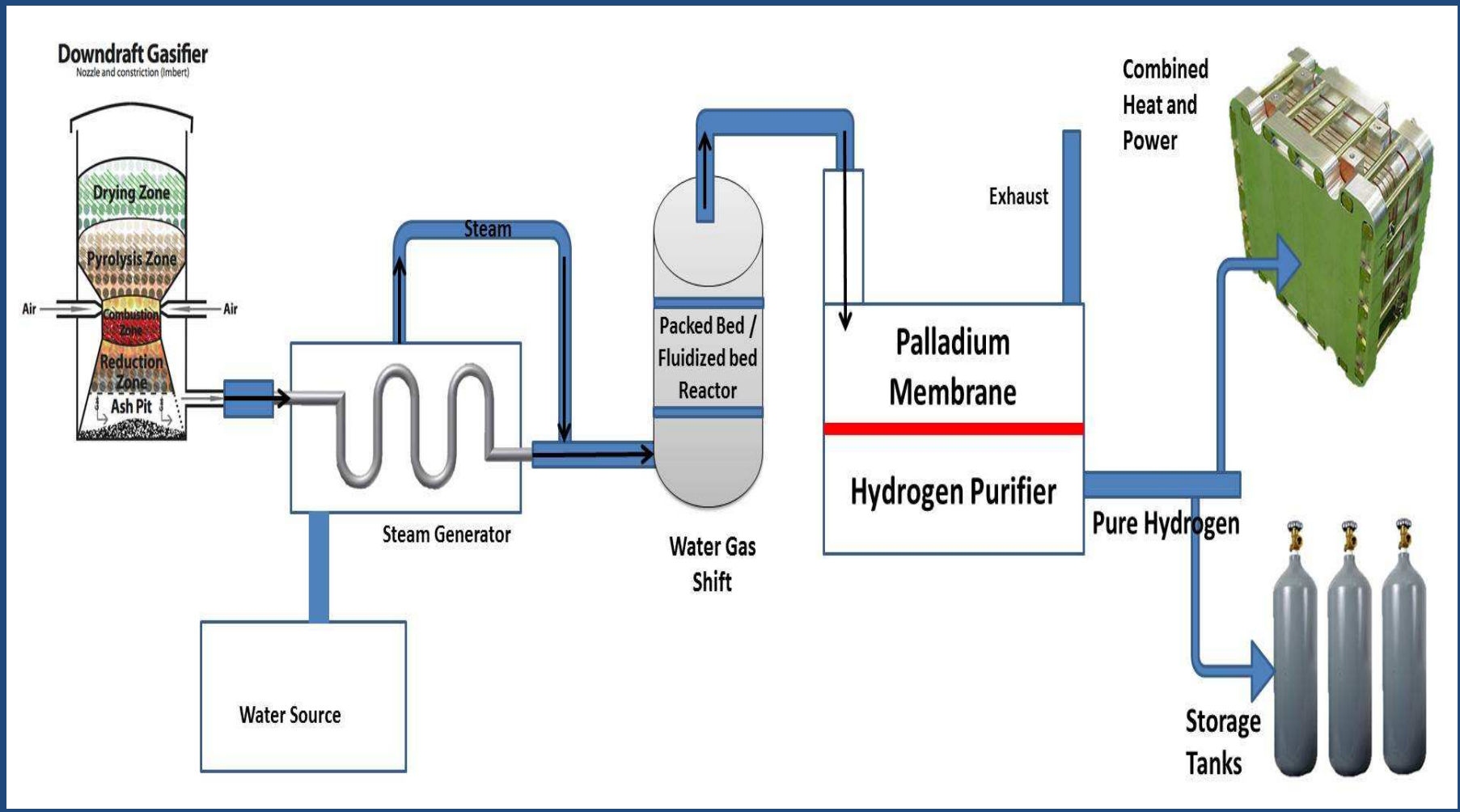
Biomass Energy

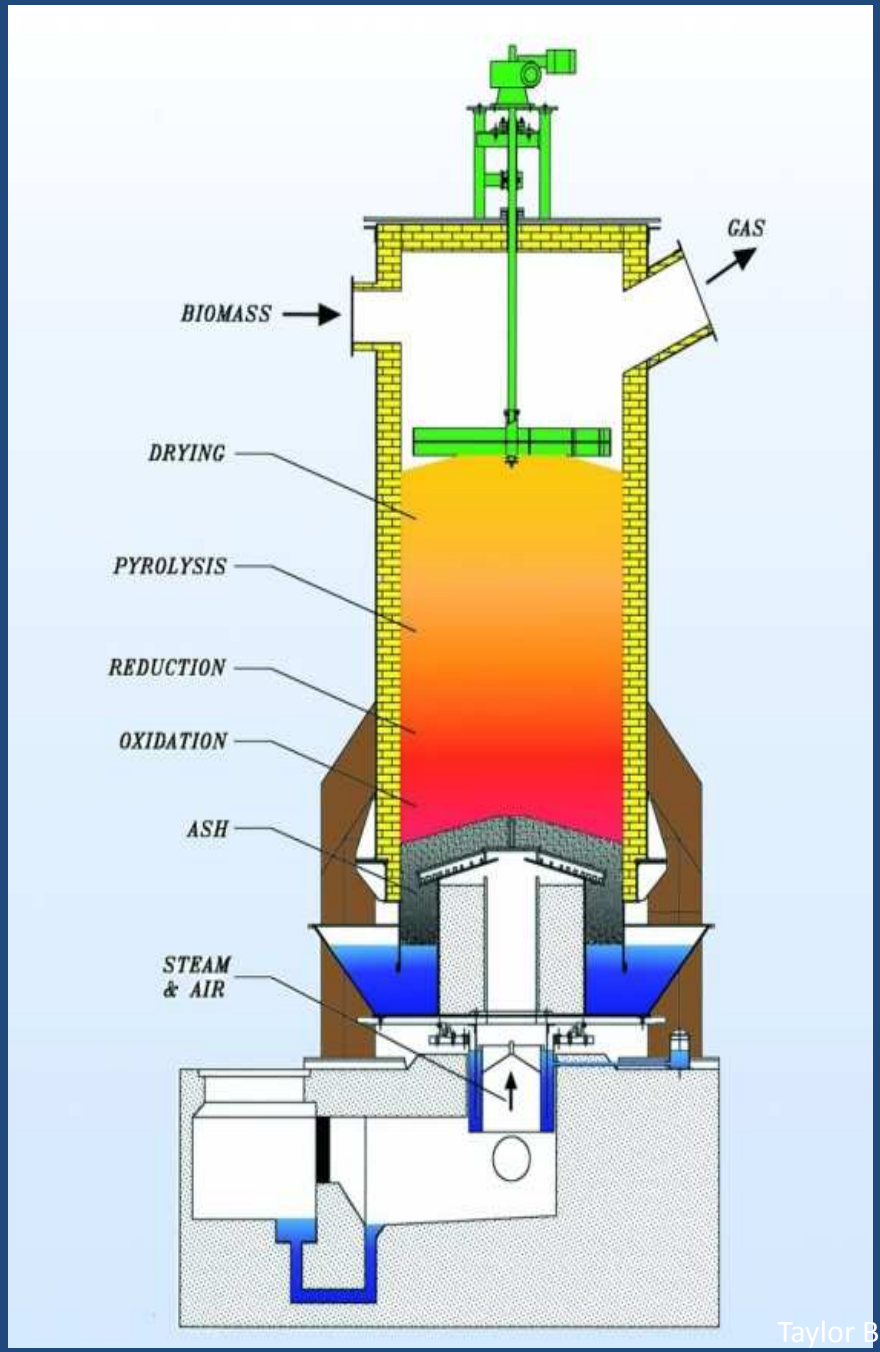
- *Excellent Potential for Economic Viability*
- *Renewable Energy Source*
- *Net Zero balance for Carbon Footprint*

General Presentation of the Hydrogen Generation from Biomass, Purification and Utilization Systems



Detailed Biomass Hydrogen Cleanup and Separation Process





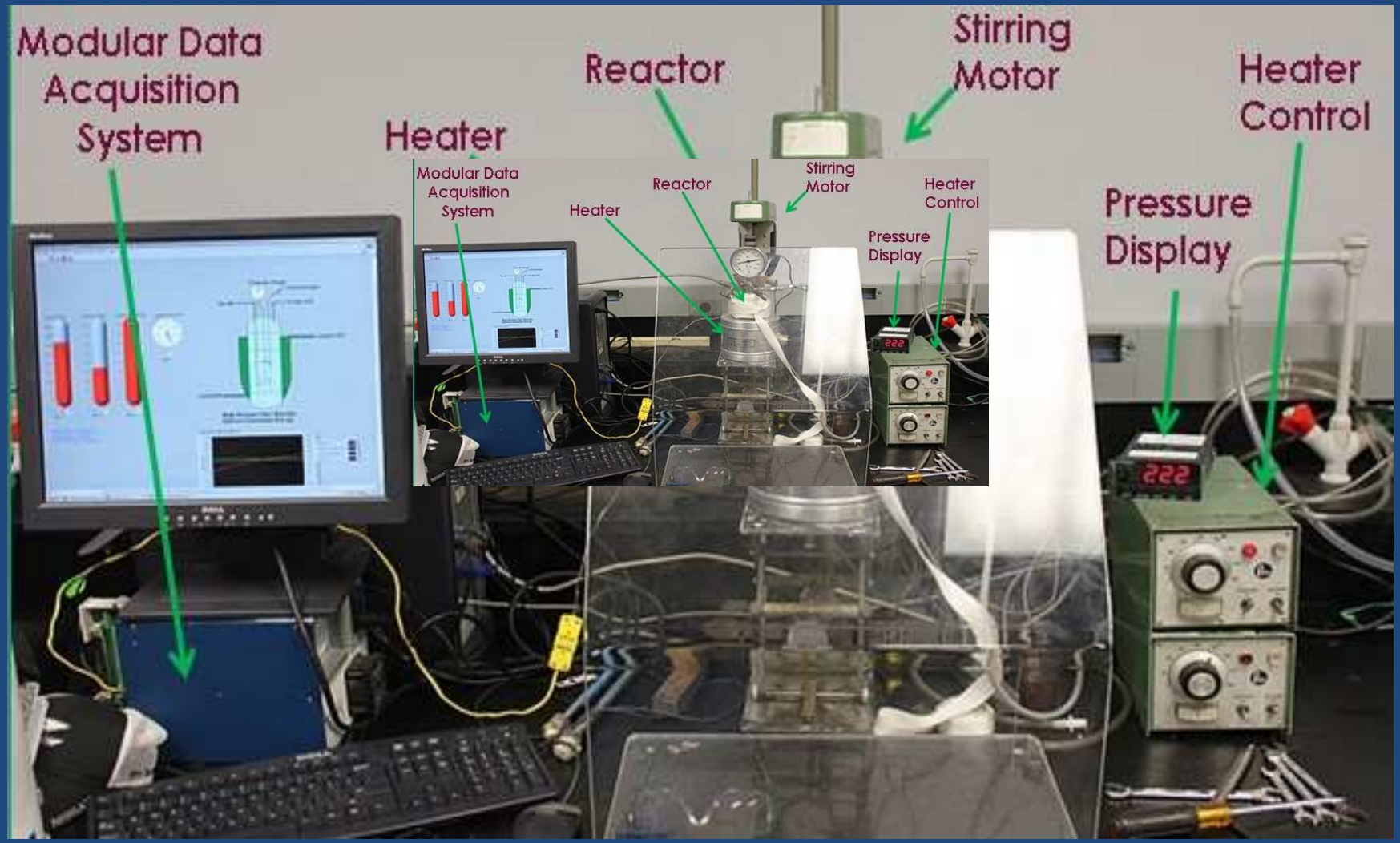
Updraft Gasifier

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

GEK v3.5 with Auger Feed Drying Bucket

Experimental Setup



Low Temperature Water Gas Shift (WGS)

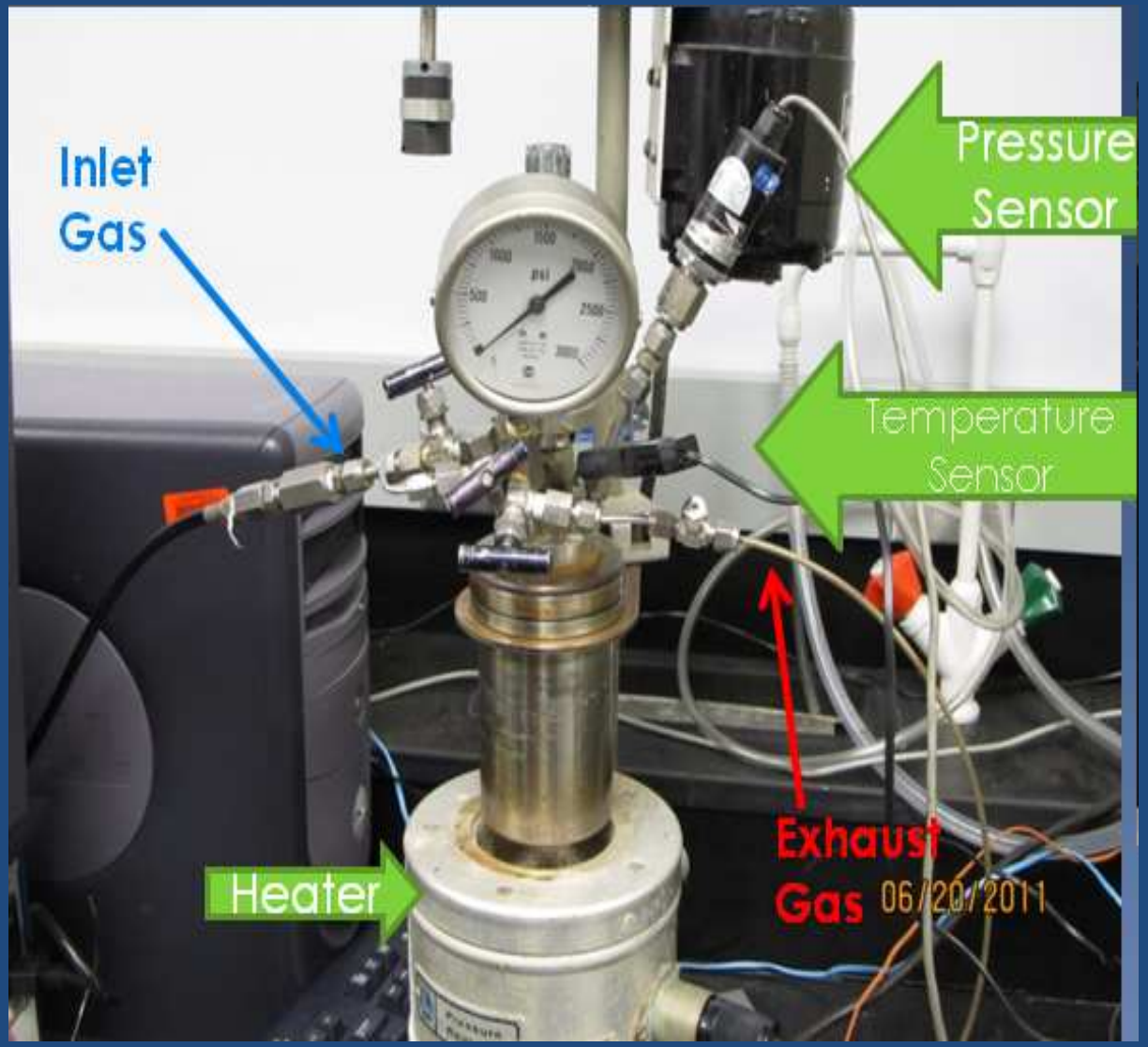
Low Temp Catalyst testing at 250 Degree C

- Copper Zinc Oxide
- Platinum Cerium Oxide (Ceria)
- Platinum Titanium Oxide
- Iron Chromium Oxide

Water Gas Shift Equation

$$CO + H_2O = CO_2 + H_2 \quad (-41.2\ kJ/mol)$$

Water Gas Shift (WGS) Reactor

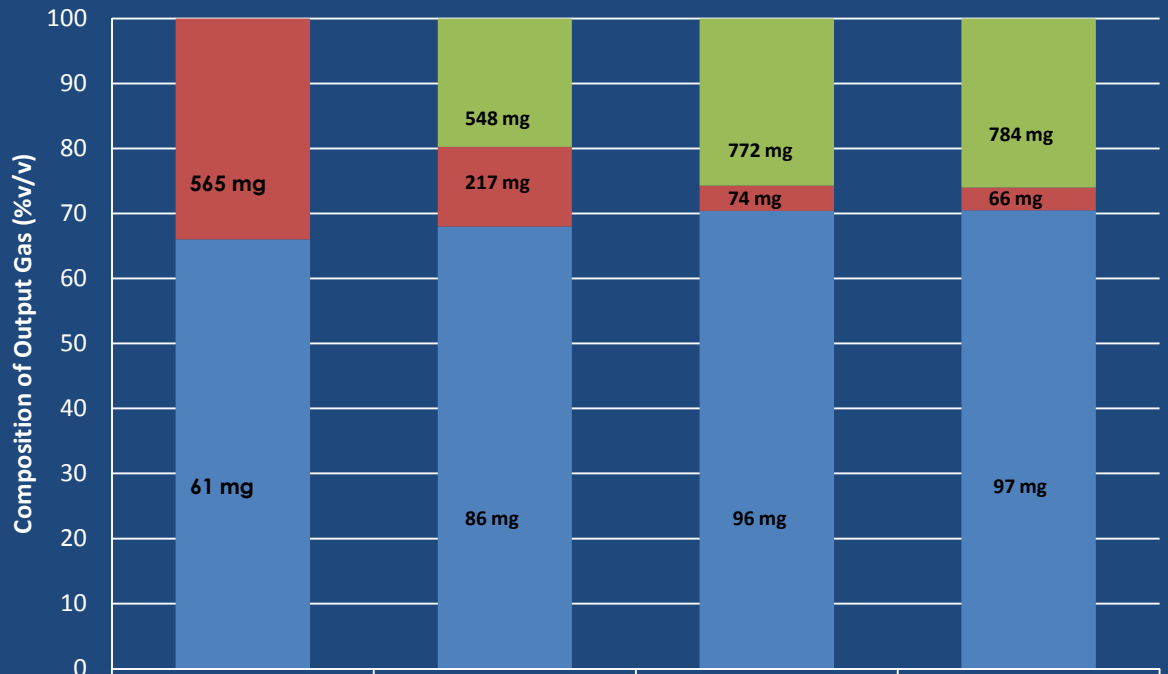


Closed Loop Reactor with Relatively Small Space Velocity and high Residence time

Slurry Mixture

- **was composed of 2 grams of ground CuZnO catalyst, 70ml of Ethylflo-164 oil, 5ml of distilled H_2O, and 50psi pre-charge of Syngas composed of 34% CO and 66% H_2. Operation temperatures were 175^oC, 200 ^oC, and 225 ^oC**

Effect of Temperature on Slurry CuZnO Catalyst Activity

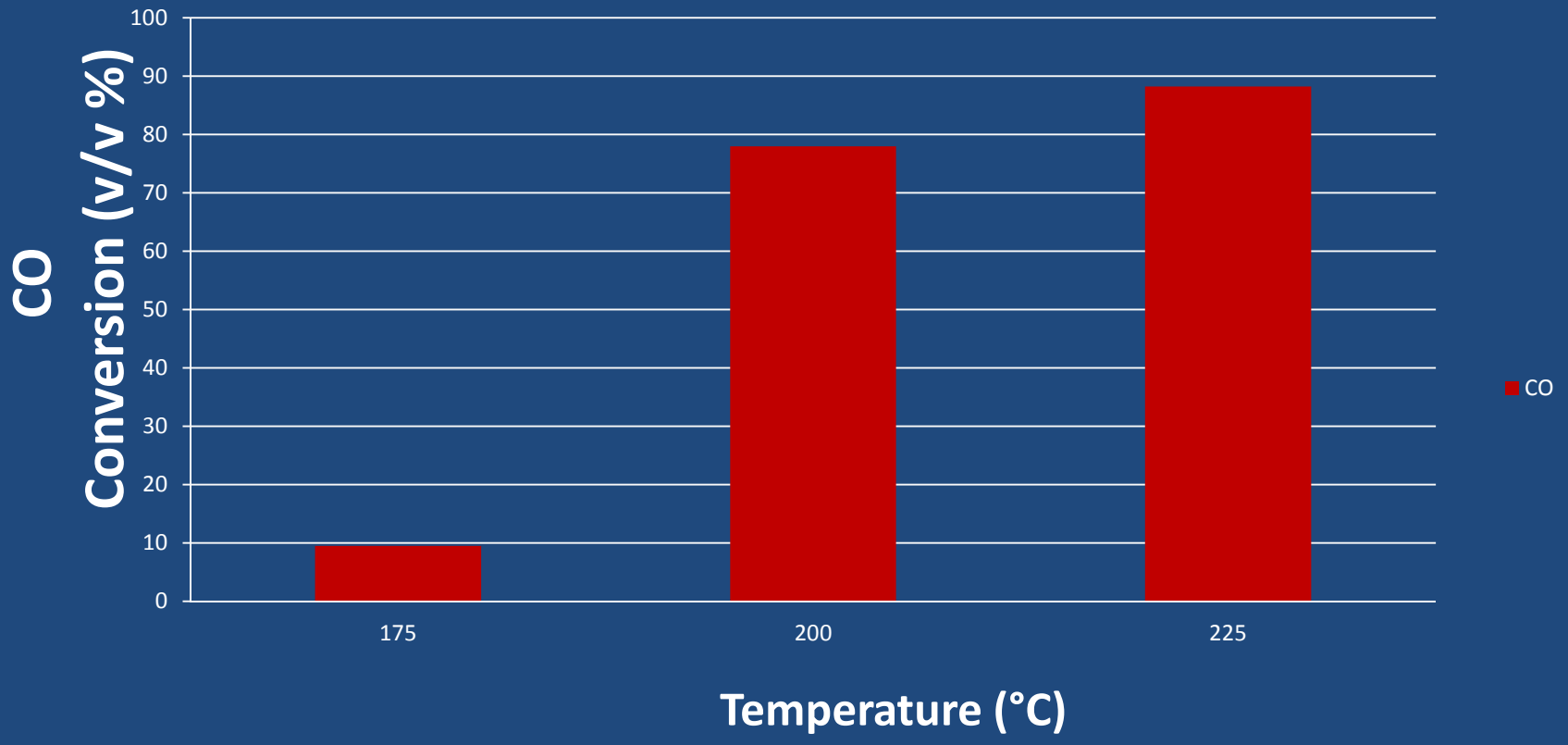


	23°C (initial)	From 175°C	From 200°C	From 225°C
CO2	0	19.73	25.73	26.02
CO	34	12.26	3.87	3.46
H2	66	68.01	70.4	70.52

This catalytic reaction was capable of bringing CO down from 34% to 3.46 % by volume and from 545 mg to 66 mg by weight

Carbon Monoxide (CO) Percentage Conversion for the CuZnO Catalyst at Different Temperature

CO Conversion at 225^{O}C is almost 90%



Packed Bed Reactor Design

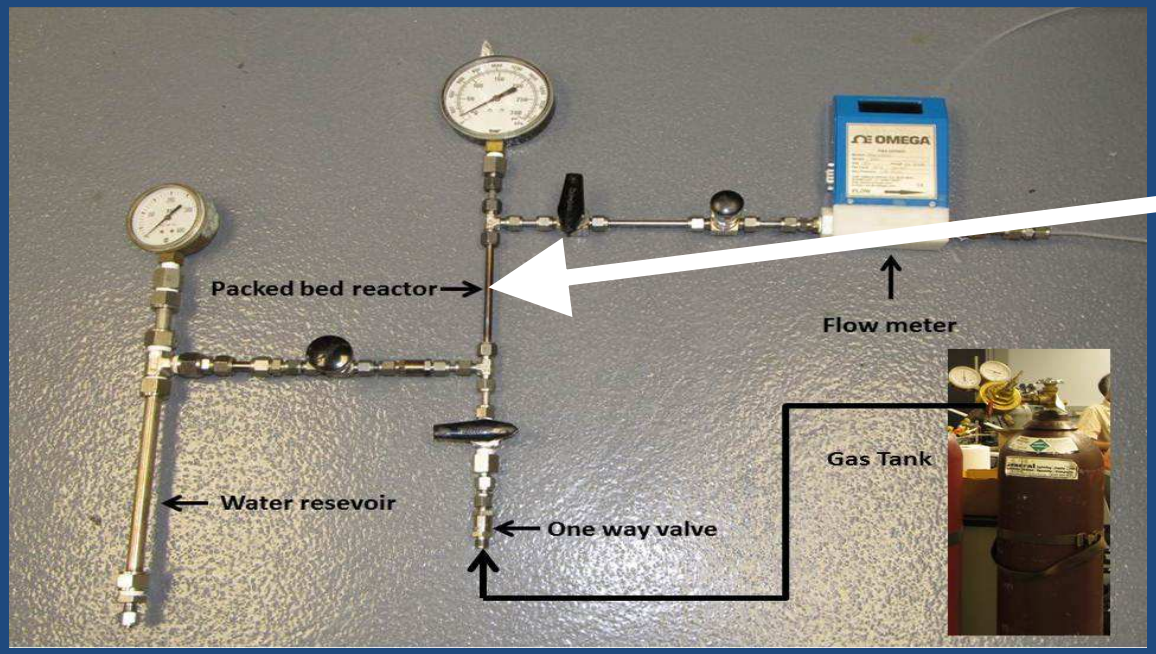
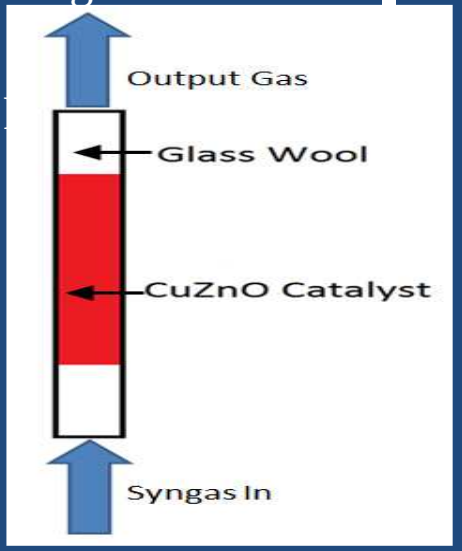


Figure 1: Experimental Apparatus

Figure 2:

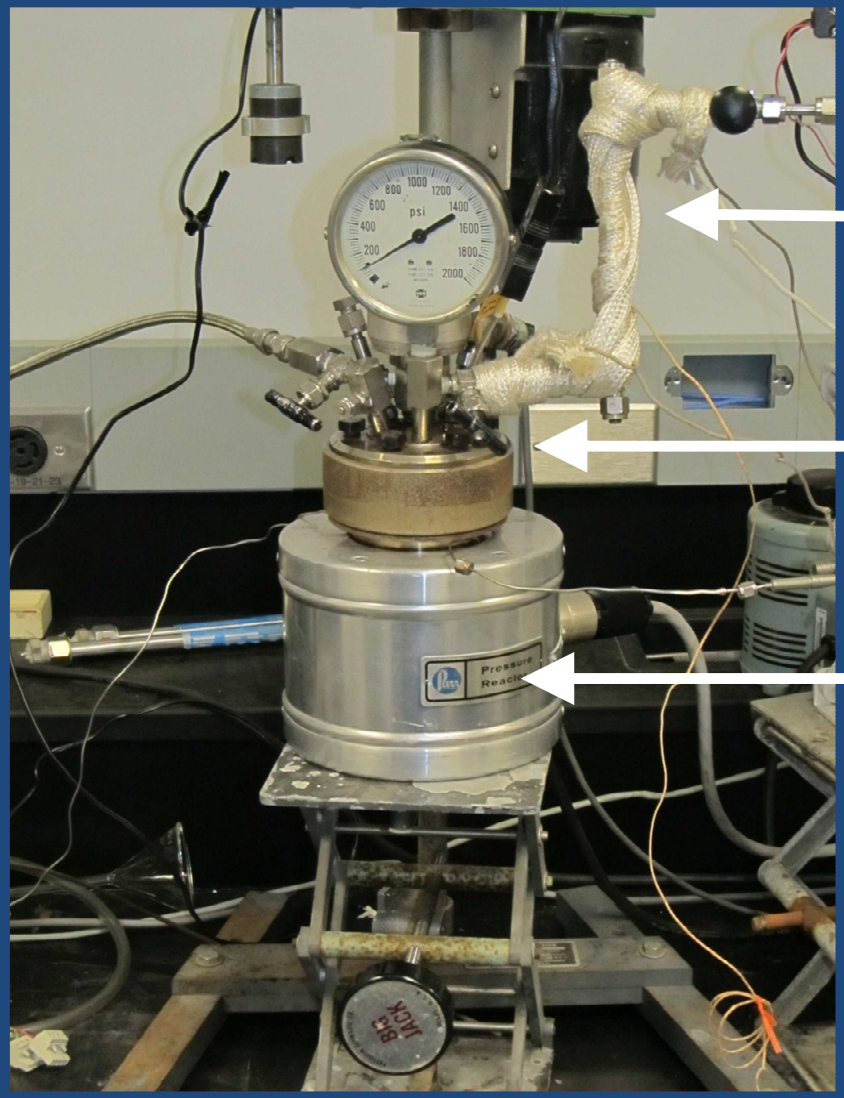


Packed Bed Reactor

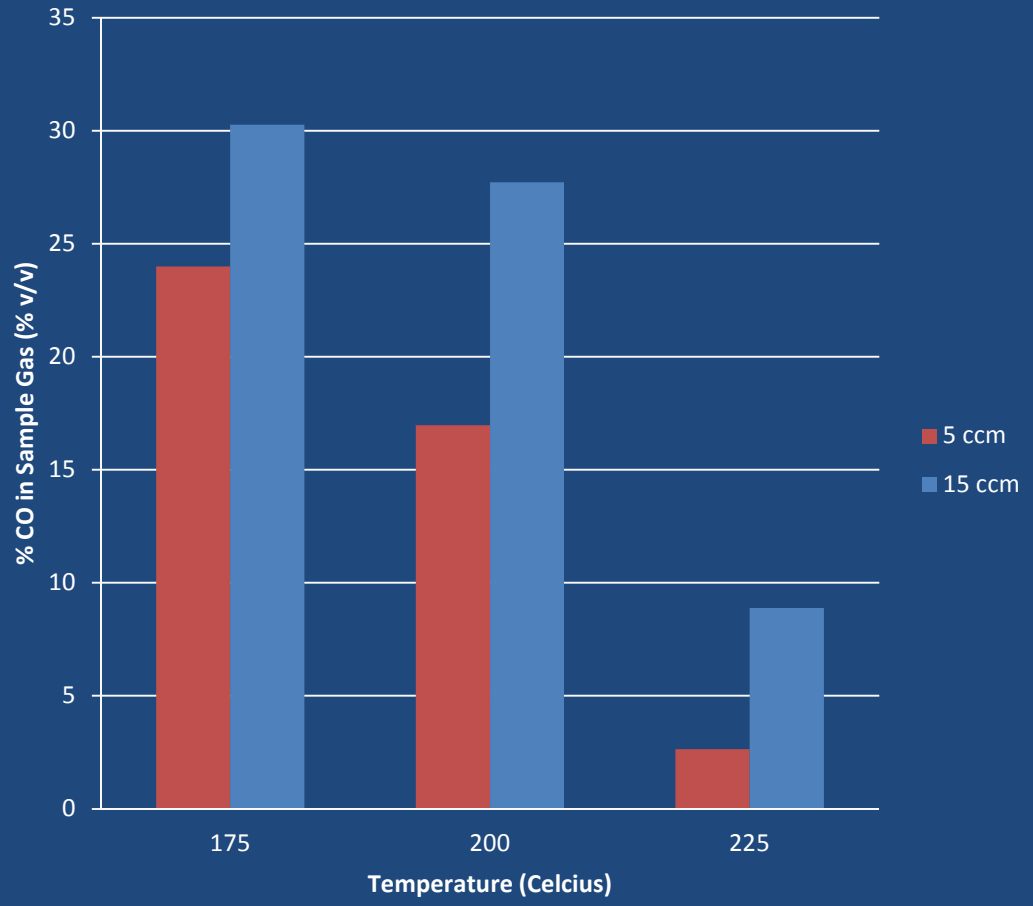
Temperature was controlled and monitored with a variable transformer and hand held digital temperature gage.

One way valve, used to prevent any feed back gas into the tank.

Packed Bed Reactor V2

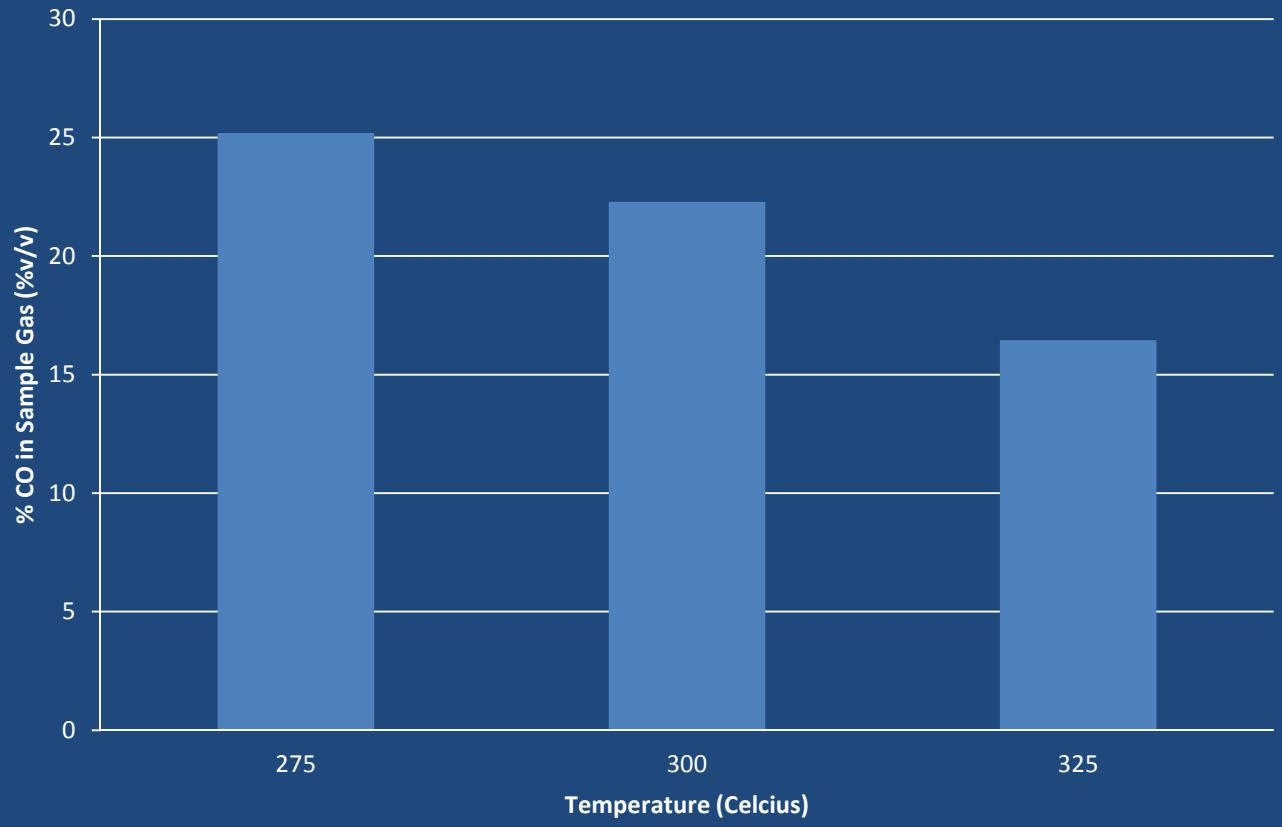


Effect of Flow Rate / Residence Time on Output Gas Composition Using Packed Bed CuZnO



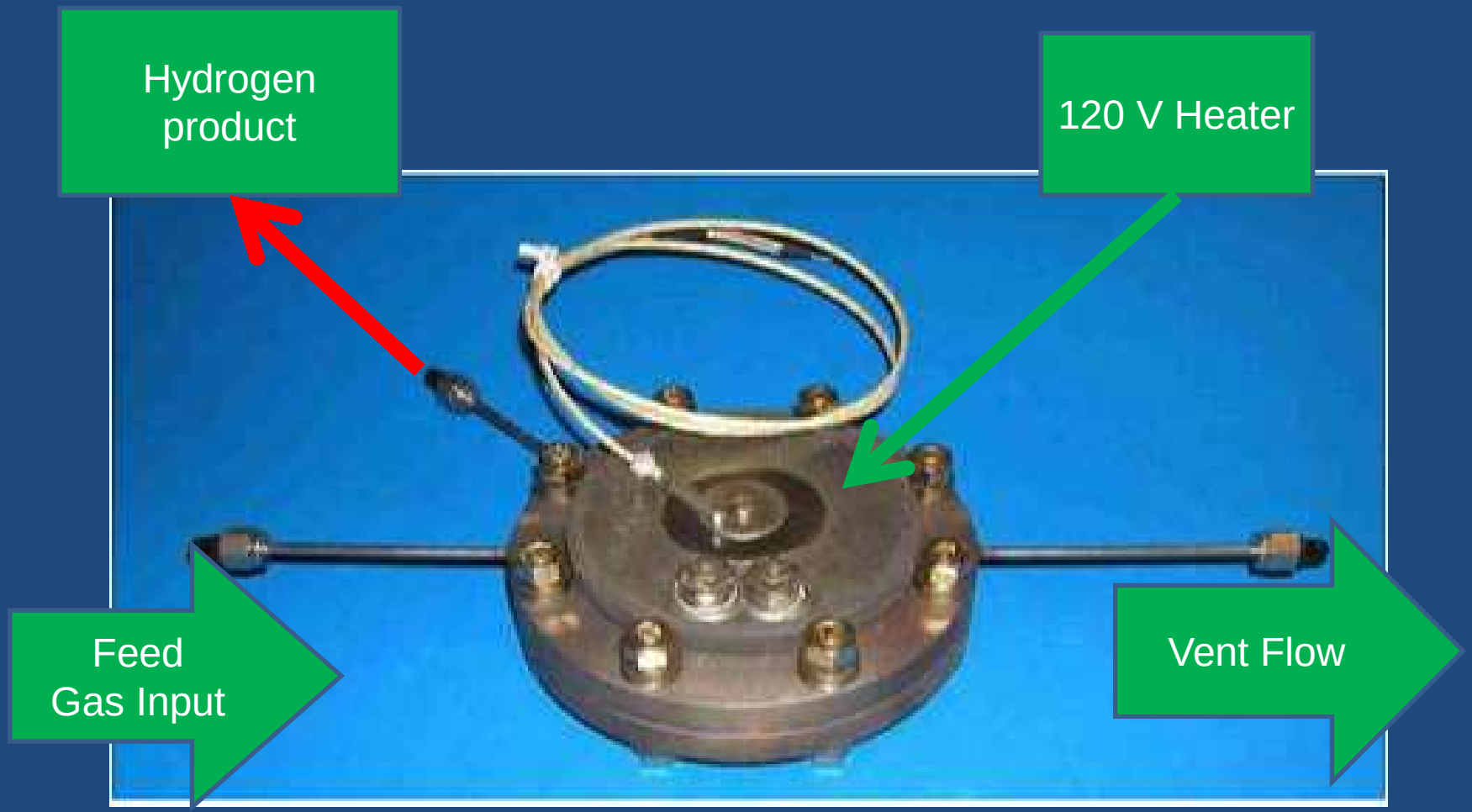
The outputs gas, after the WGS reaction at 225^{o}C, the CO concentration was lowered to (2.64%) from 34% at flow rate of 5ccm and the CO concentration was lowered to (8.3%) from 34% at flow rate 15 ccm

Iron Chromium Oxide Performance in WGS Reaction at Various Temperatures in a Packed Bed Reactor



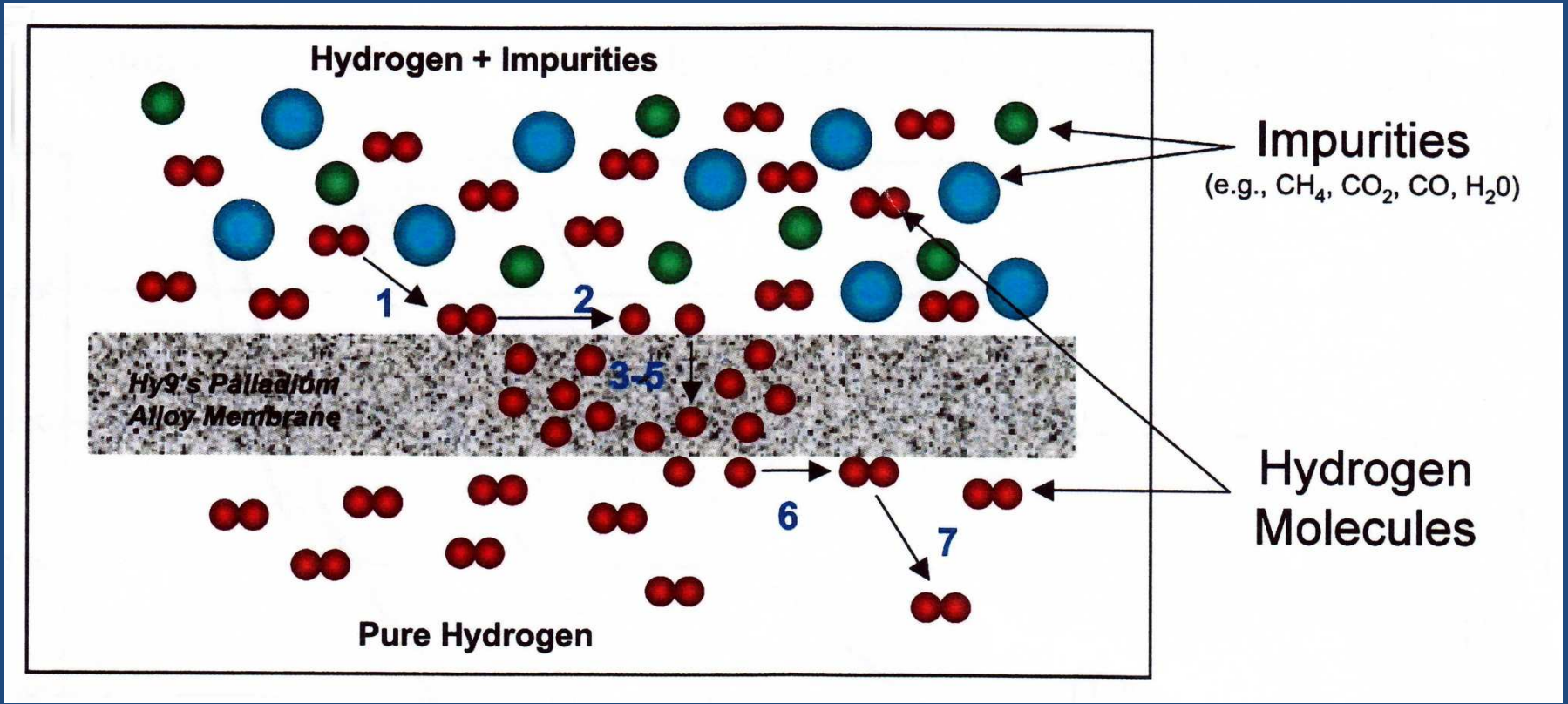
Initial CO concentration (34 %) in the input gases at room temp - output gases CO concentration , after the WGS reaction at all three temperatures

Testing Small Scale Hydrogen Purifier



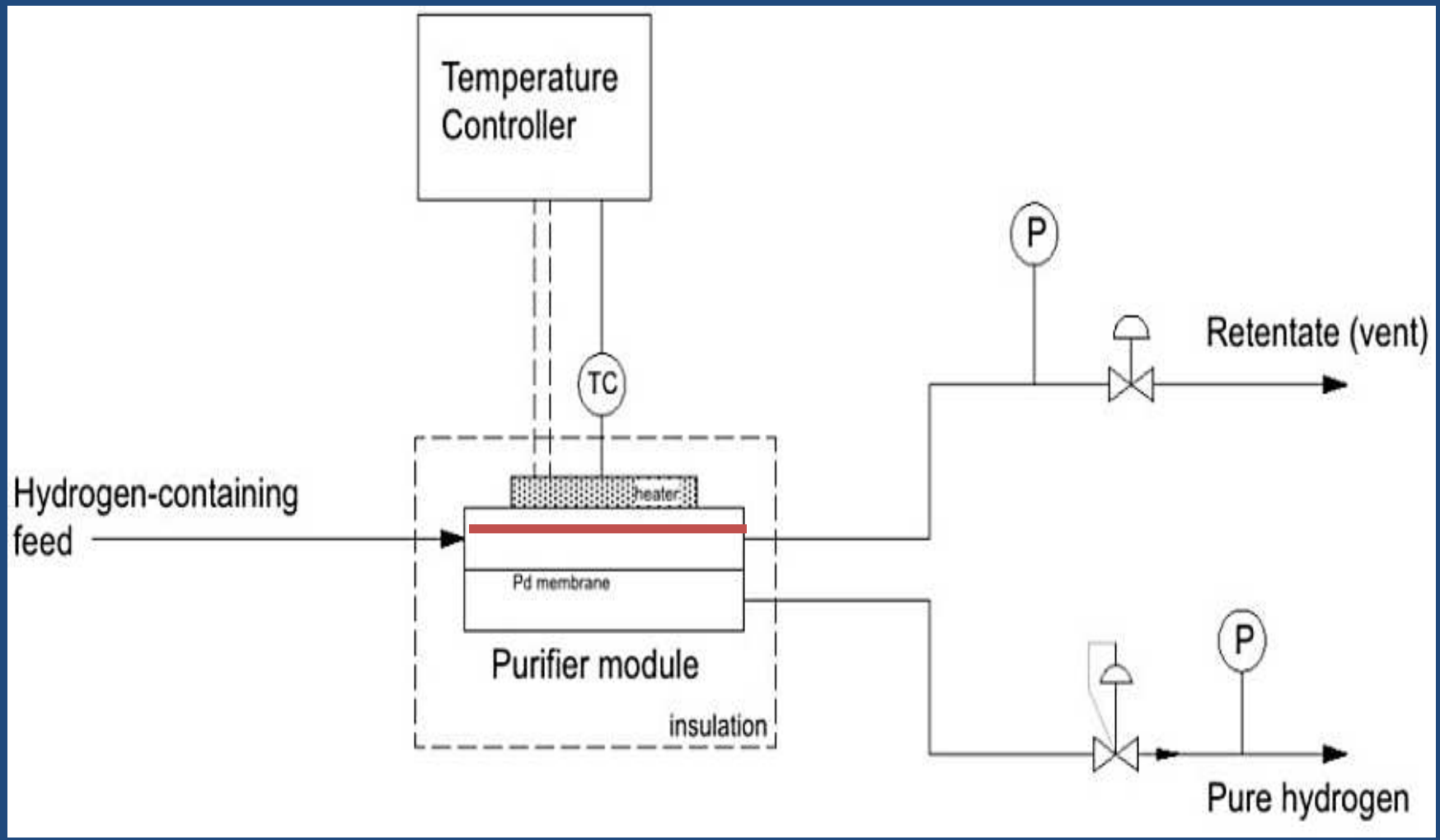
Palladium Membrane Technology

- How does the Palladium membrane purify the hydrogen?
  - http://www.hy9.com/membranepure.html

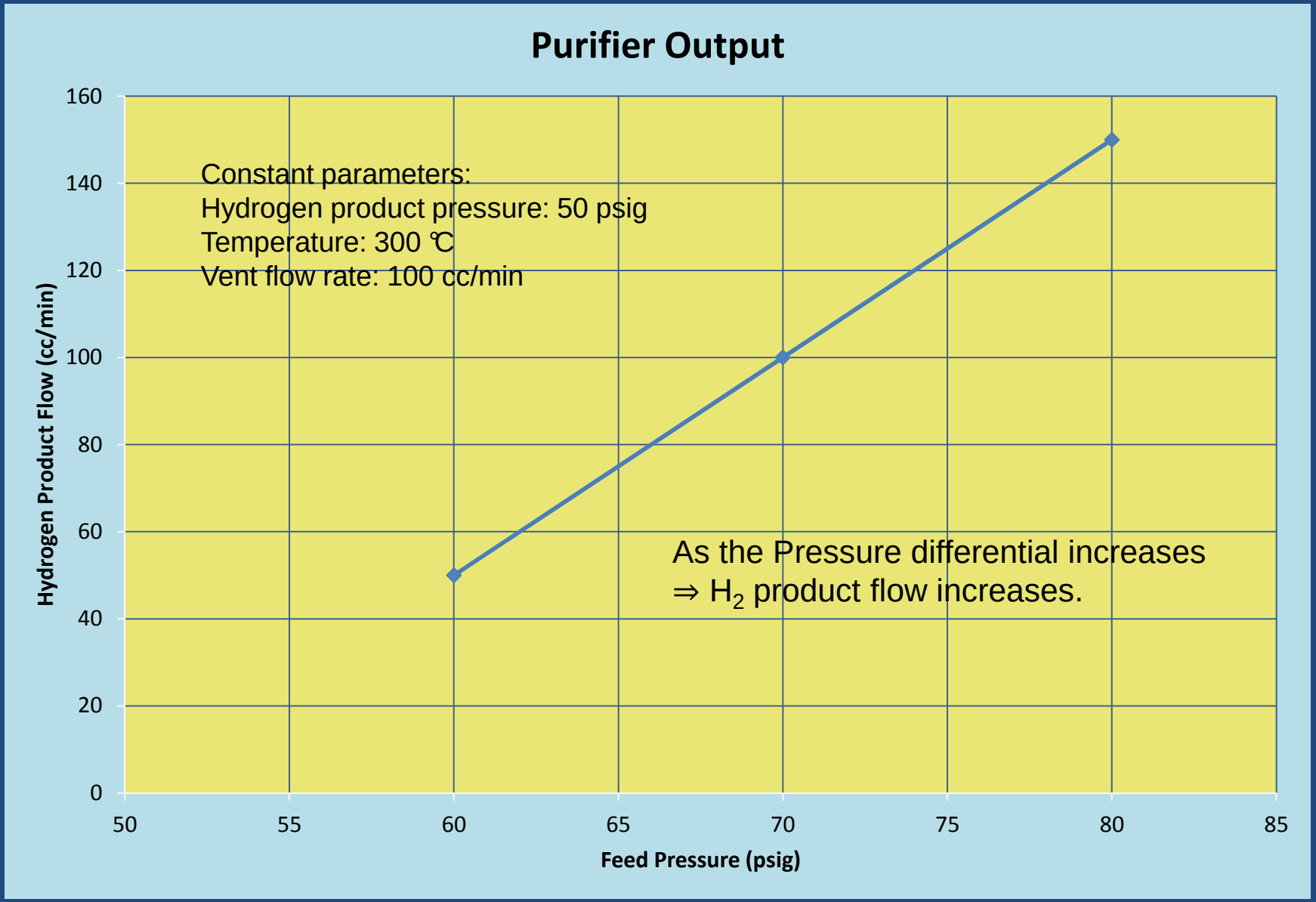


Palladium Membrane Purifier

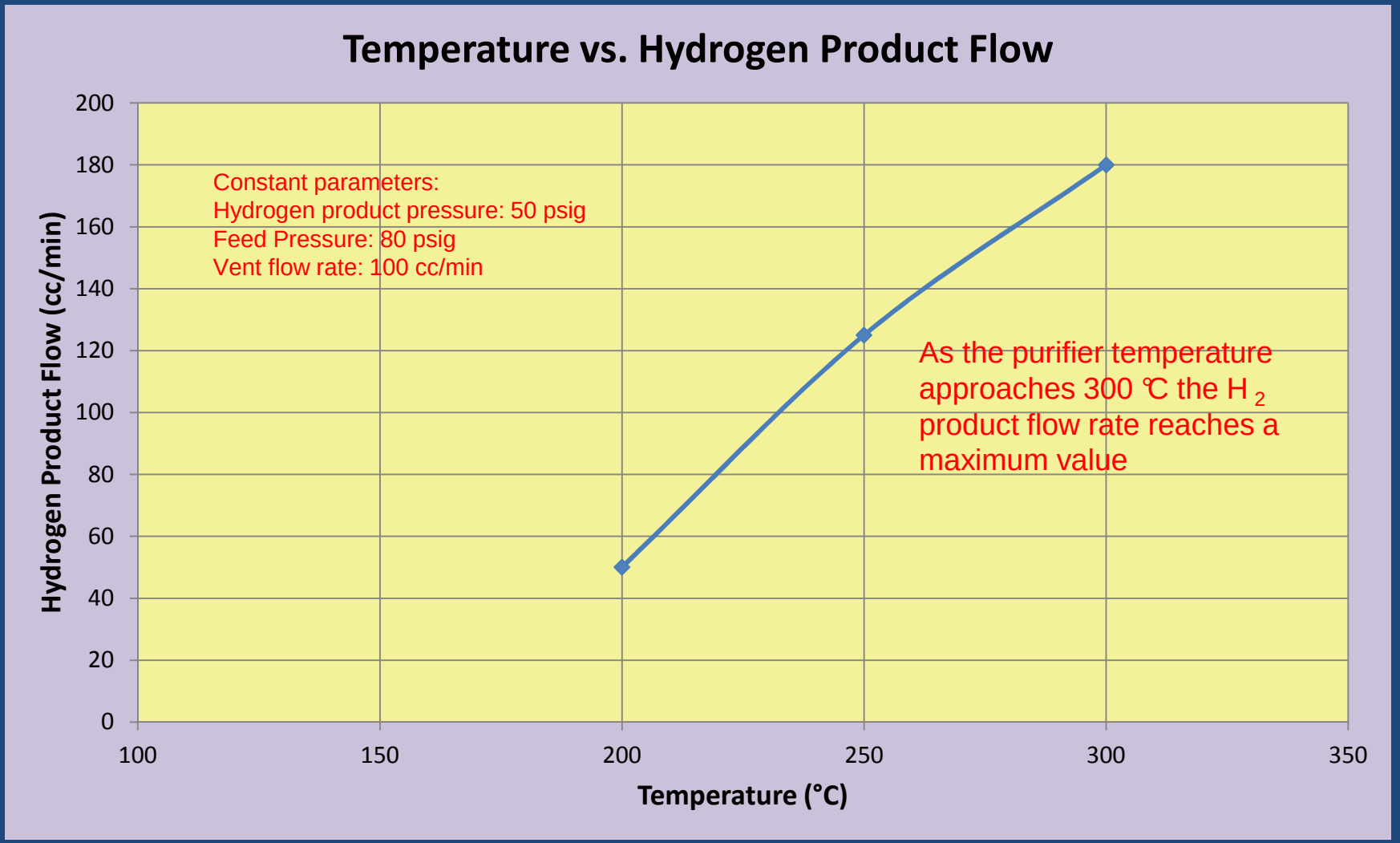
- The orientation of the palladium membrane in this hydrogen purifier is parallel with respect to the flow of the syngas.



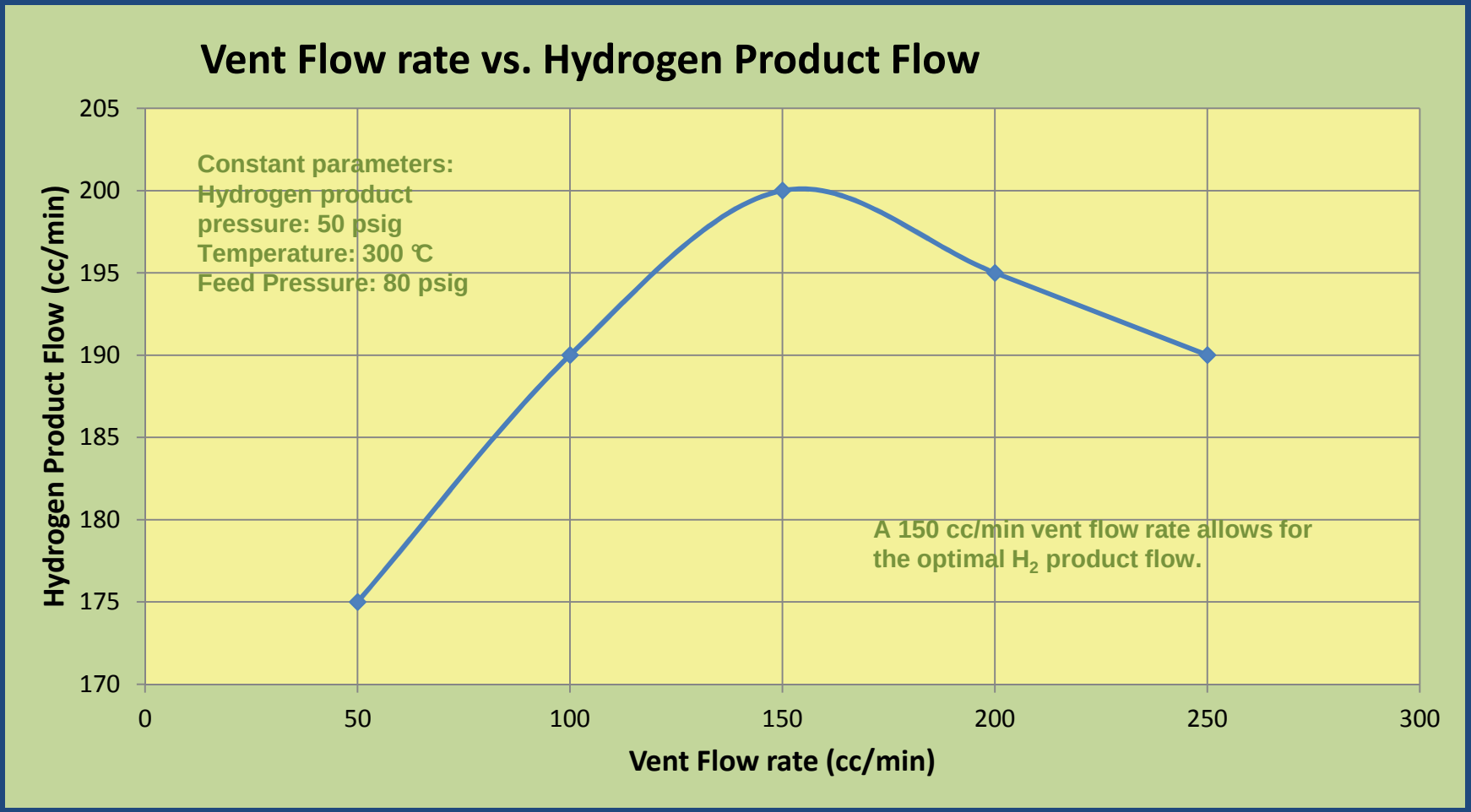
Hydrogen Purifier Experimental Results

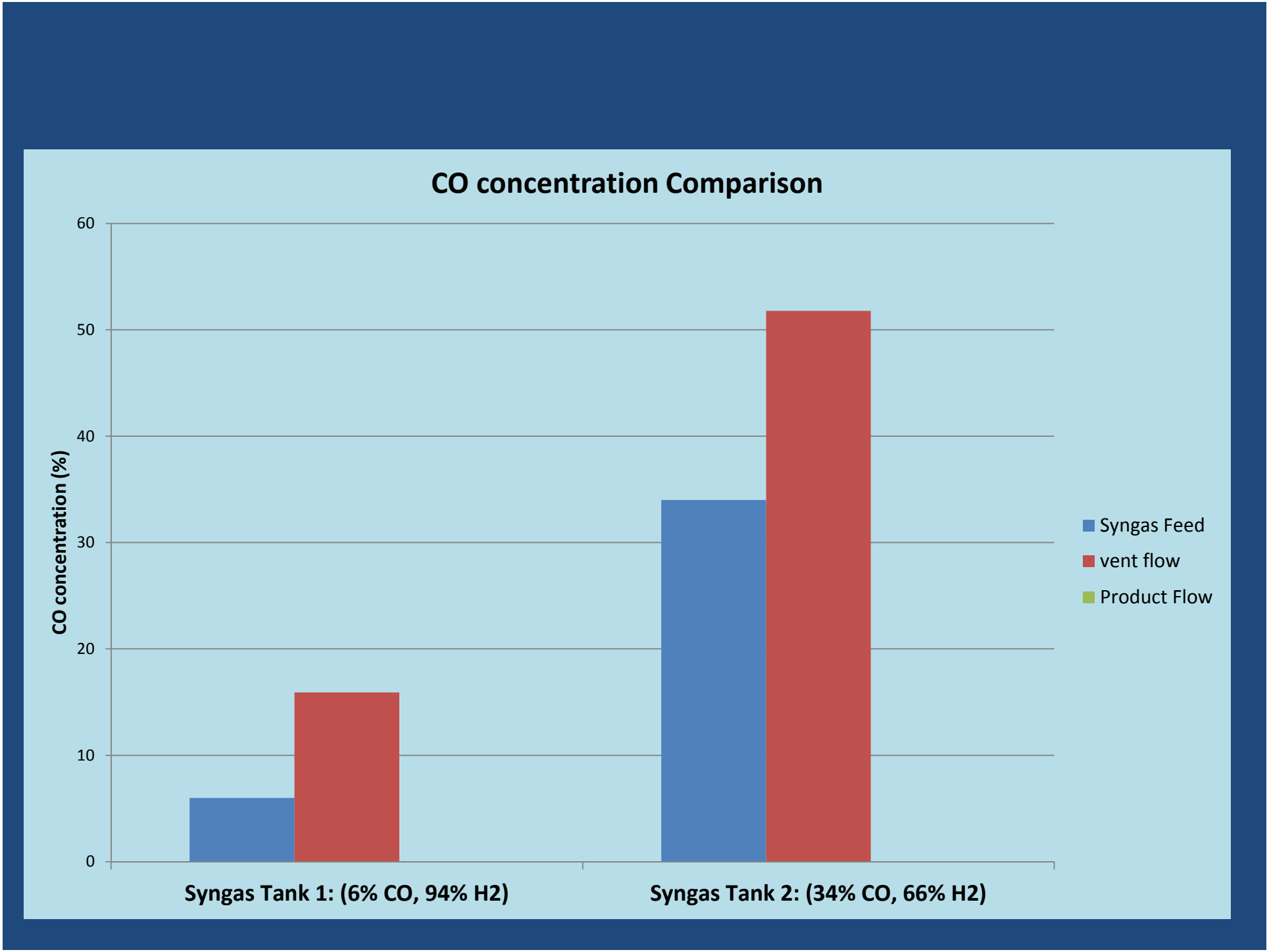


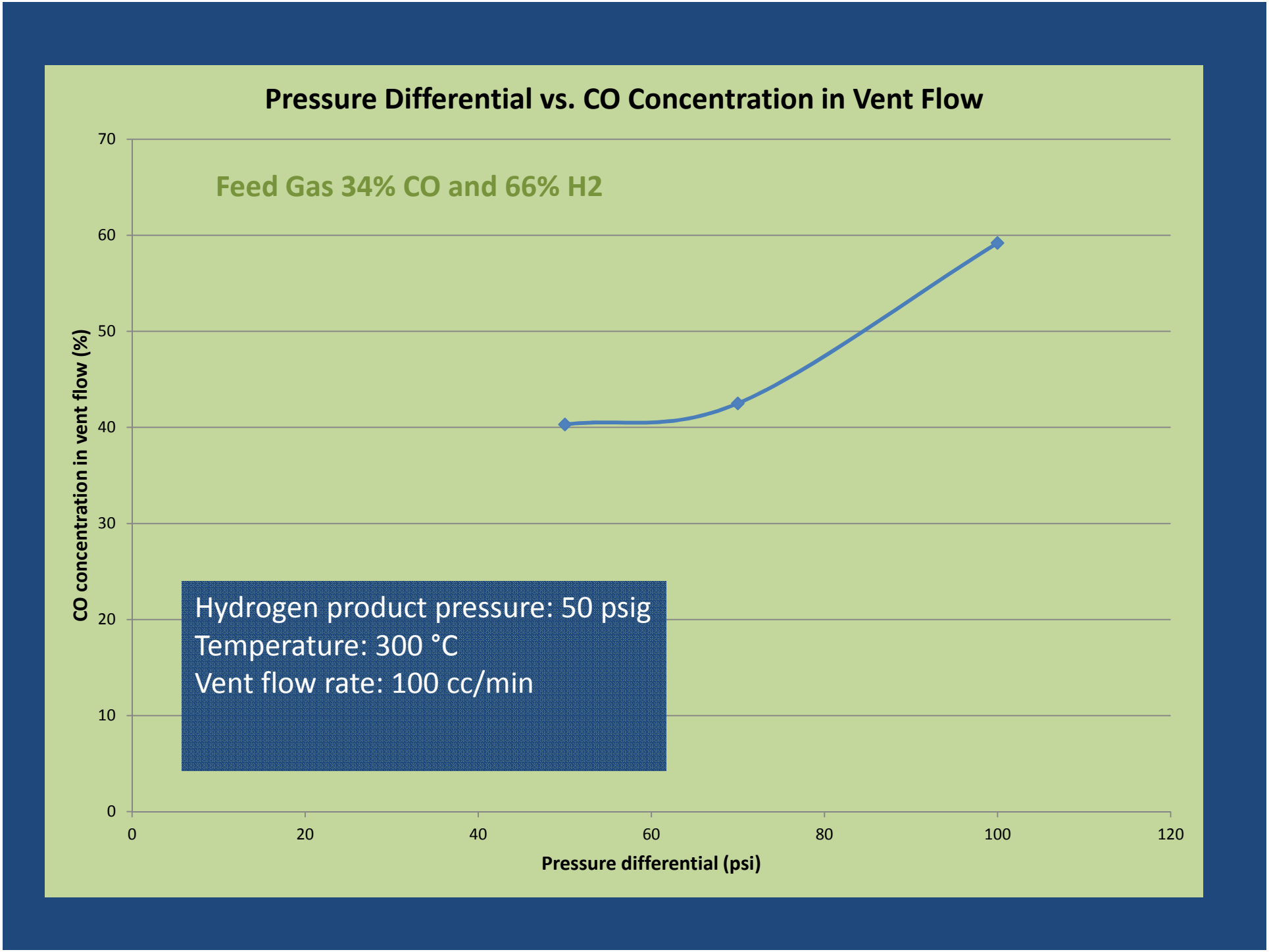
Effect of Temperature on H2 Output



Effect of Vent Flow Rate on H2 output




CO concentration Comparison
CO concentration (%)
60
50
40
30
20
10
0
Syngas Feed
vent flow
Product Flow
Syngas Tank 1: (6% CO, 94% H2)
Syngas Tank 2: (34% CO, 66% H2)


Pressure Differential vs. CO Concentration in Vent Flow
Feed Gas 34% CO and 66% H2
Hydrogen product pressure: 50 psig
Temperature: 300 °C
Vent flow rate: 100 cc/min
CO concentration in vent flow (%)
Pressure differential (psi)
0
10
20
30
40
50
60
70
0
20
40
60
80
100
120

Conclusions

- CuZnO Catalyst provided very promising results for both closed and open loop Water Gas Shift Reaction Systems
- CO was reduced from 34% to 3.46 % and 2.64% in closed and open loop Water Gas Shift Reaction Systems respectively
- Hydrogen Purification System provided 0% CO and 99.9999% pure H2
- This Hydrogen Cleanup system is will poised for scale up to produce 75 SLM Pure H2