

Fuel combustion vs. nuclear heated

Reforming



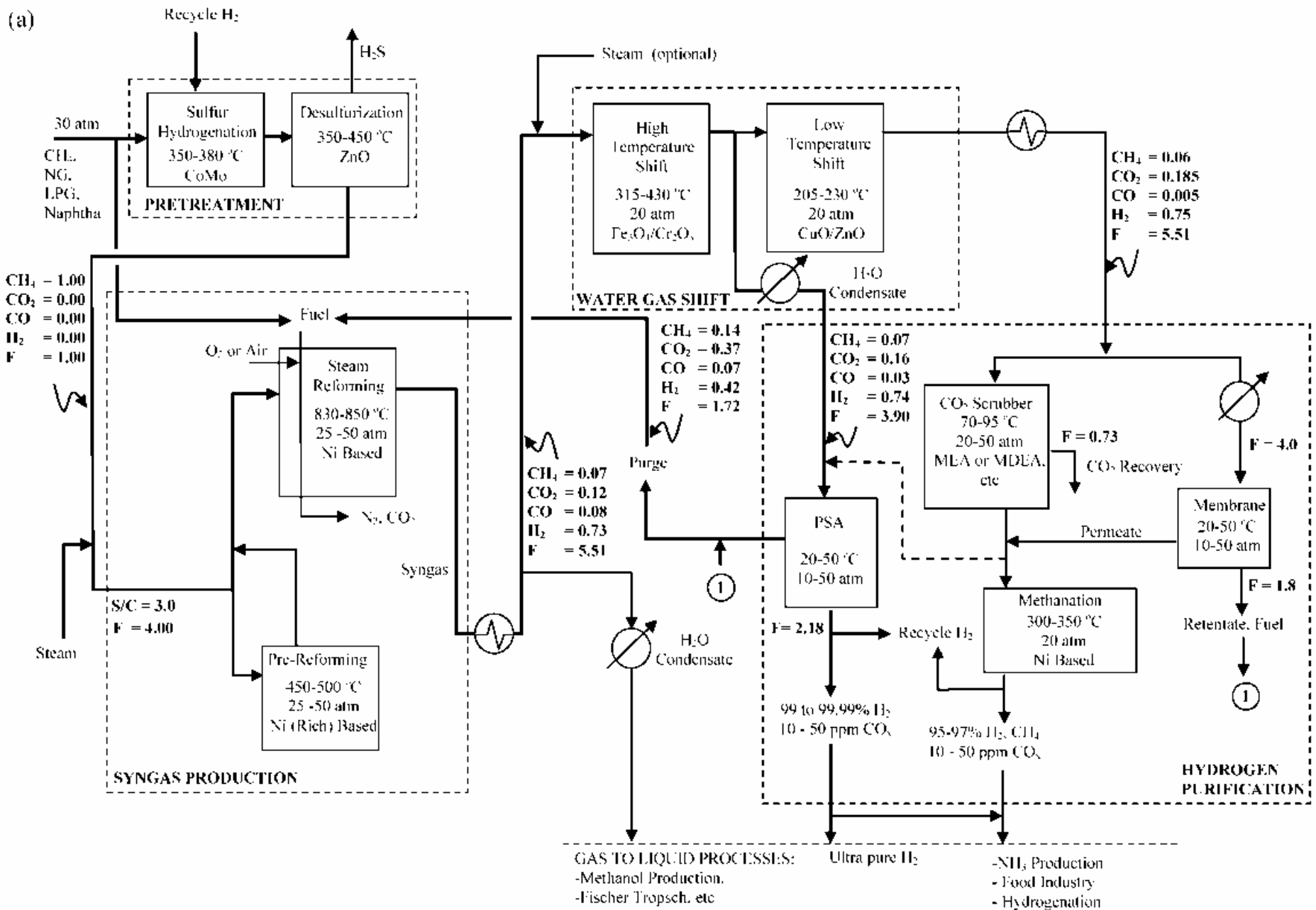
Endothermic

Water gas shift

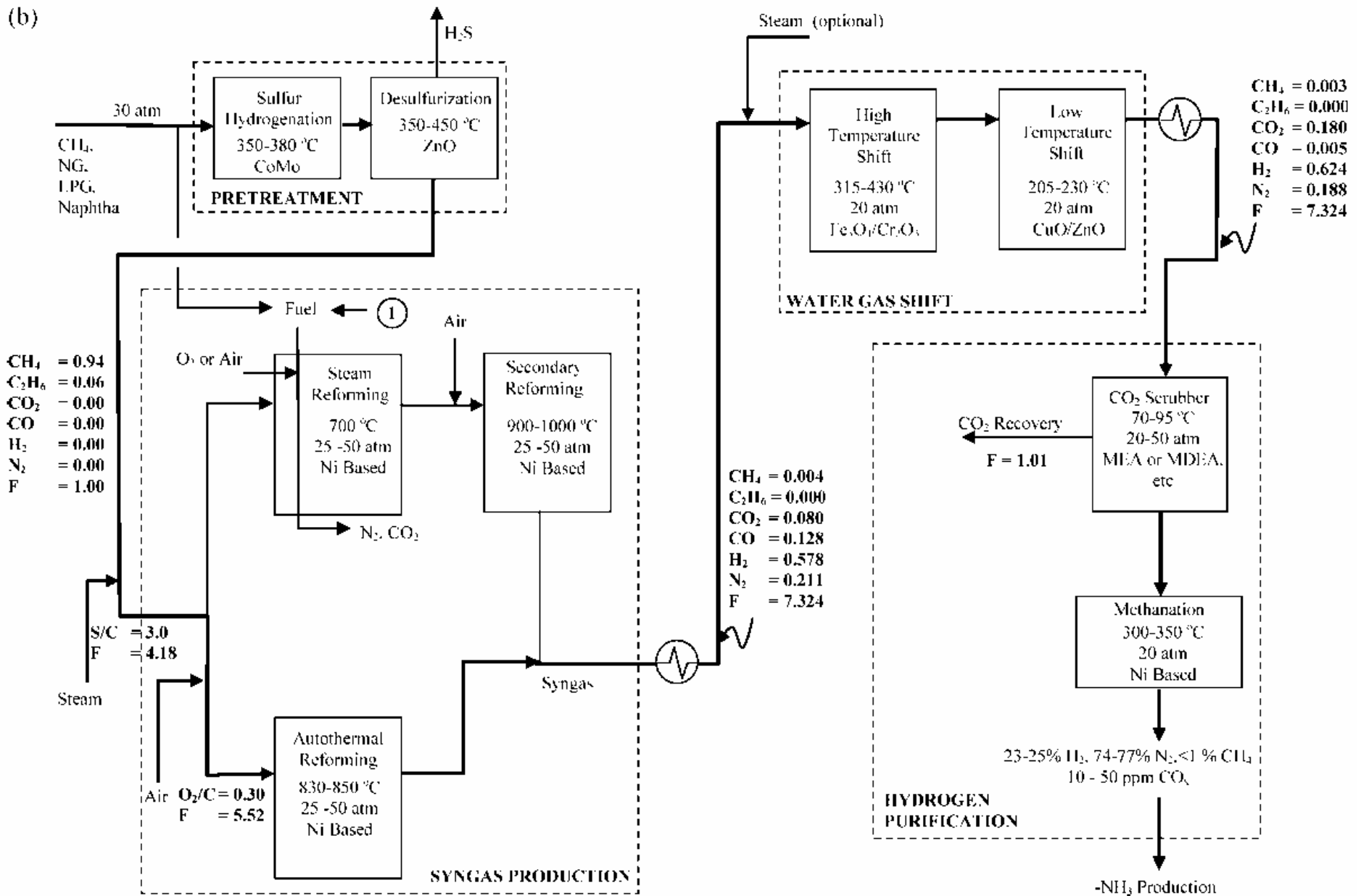


Exothermic

Large H reforming systems



Large H₂ reforming systems. Close- up



Real world examples

Licensors H ₂ plants	System	Sizes (MMsfd)	Plants worldwide
Linde AG	SR-WGS(HT)-PSA	1–100	250
Technip	SR-WGS(HT)-PSA	—	220
Uhde	SR-WGS(HT)-PSA	–130	56
Haldor Topsøe	SR-WGS(HT)-PSA	0.2–200	21
UOP LLC	PSA (Polybed)	–200	700
UOP LLC	Membrane (Polysep)	–320	50
Howe-Baker engineers	SR-WGS(HT)-PSA	1–90	170
Foster wheeler	SR-WGS(HT)-PSA	1–95	100
Lurgi Oel-Gas-Chemie	SR-WGS(HT)-PSA	1–200	105
Haldor Topsøe	Methanol SR-PSA	–1	10
Air products	Membrane (PRISM)	—	270
Air products	PSA (PRISM)	15–120	270

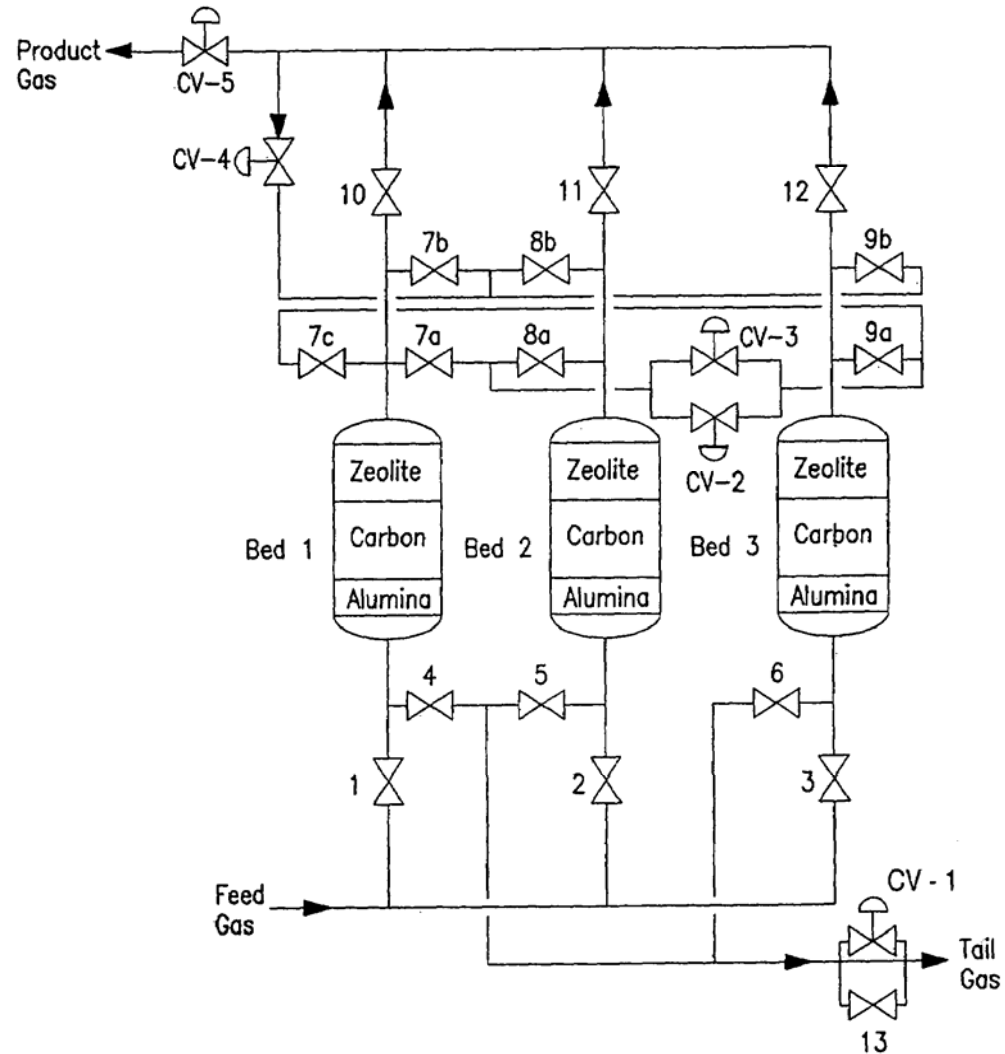
Reference: Hydrocarbon Processing, Gas Processes 2002, Gulf Publishing Co.
 SR = steam reforming, WGS = water gas shift, HT = High temperature, PSA = pressure swing adsorption.

Pressure swing adsorption PSA

Basic principles:

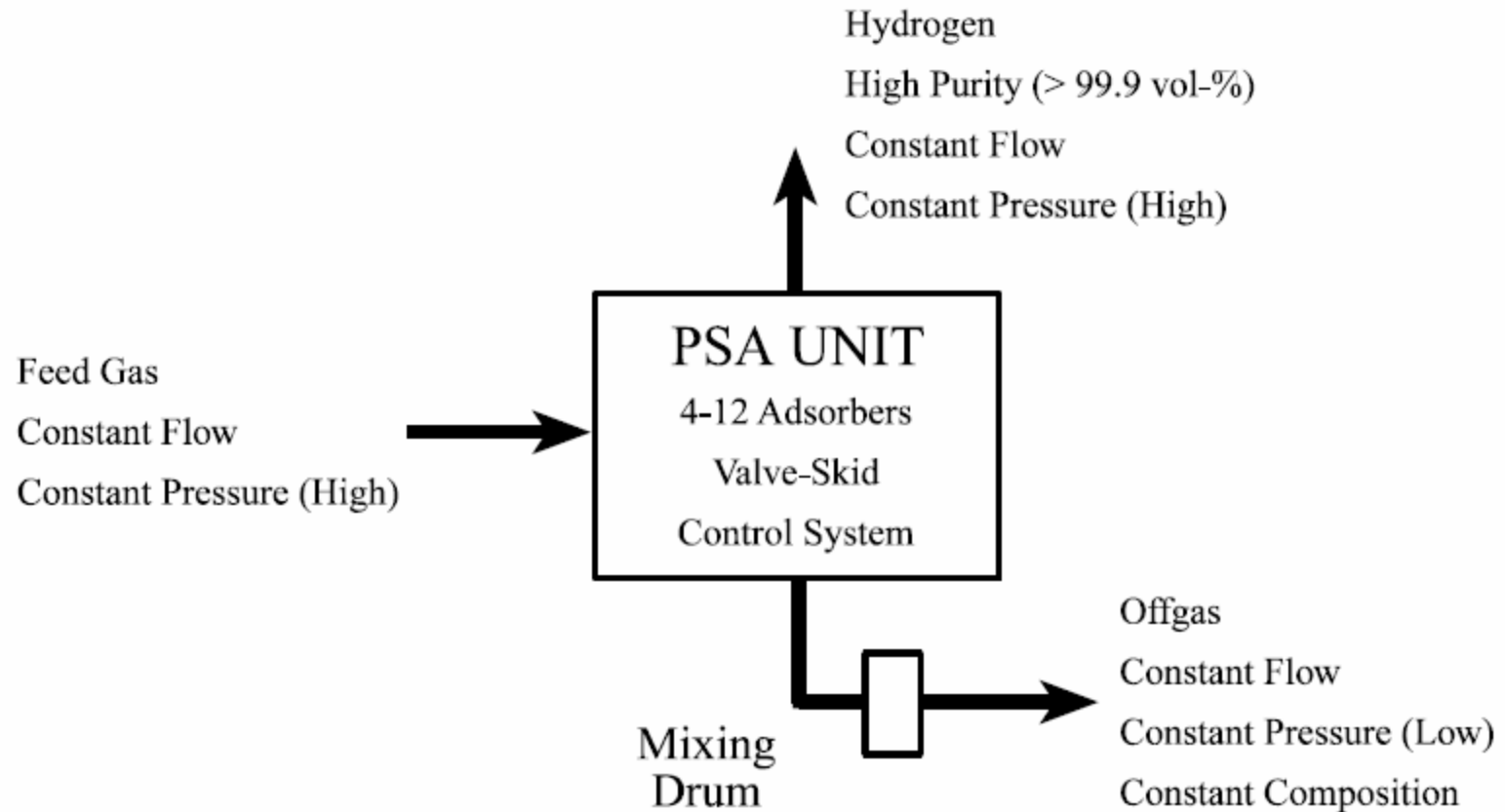
Adsorption
difference of
H₂ and CO₂
due to the
difference in
the Van Der
Waals force,
mass.

Schematic diagram for a three bed PSA system



Pressure swing adsorption PSA

PSA Basic Flow Scheme



PSA Column



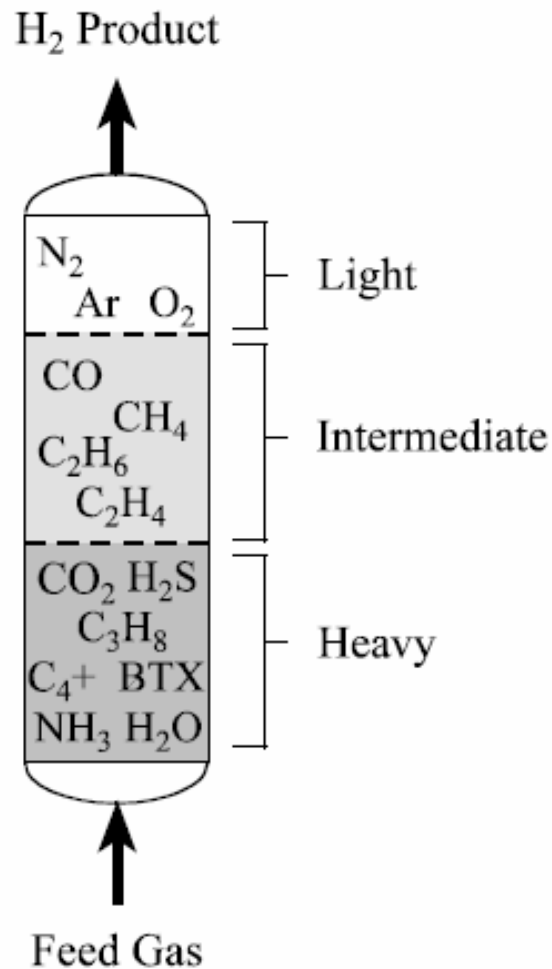
NPRE 470 H₂ and Fuel Cells

PSA Valve Stacks

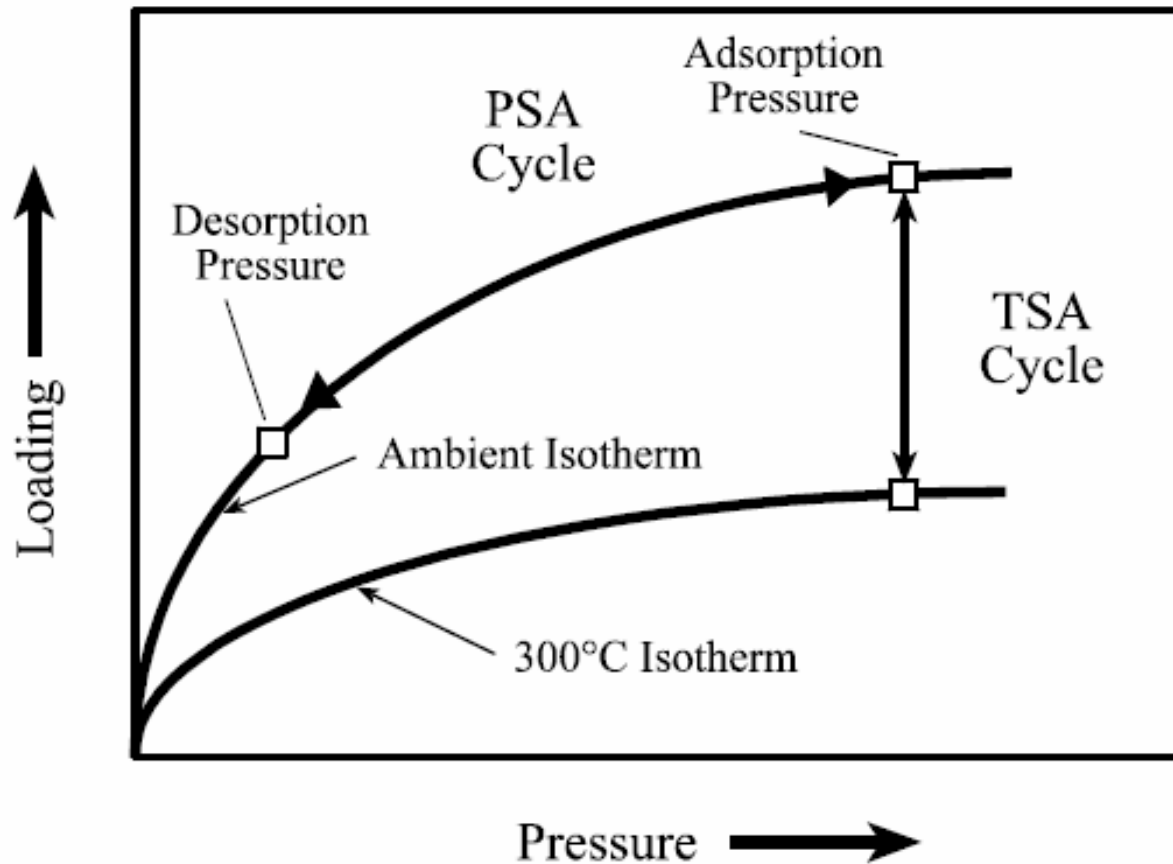


NPRE 470 H2 and Fuel Cells

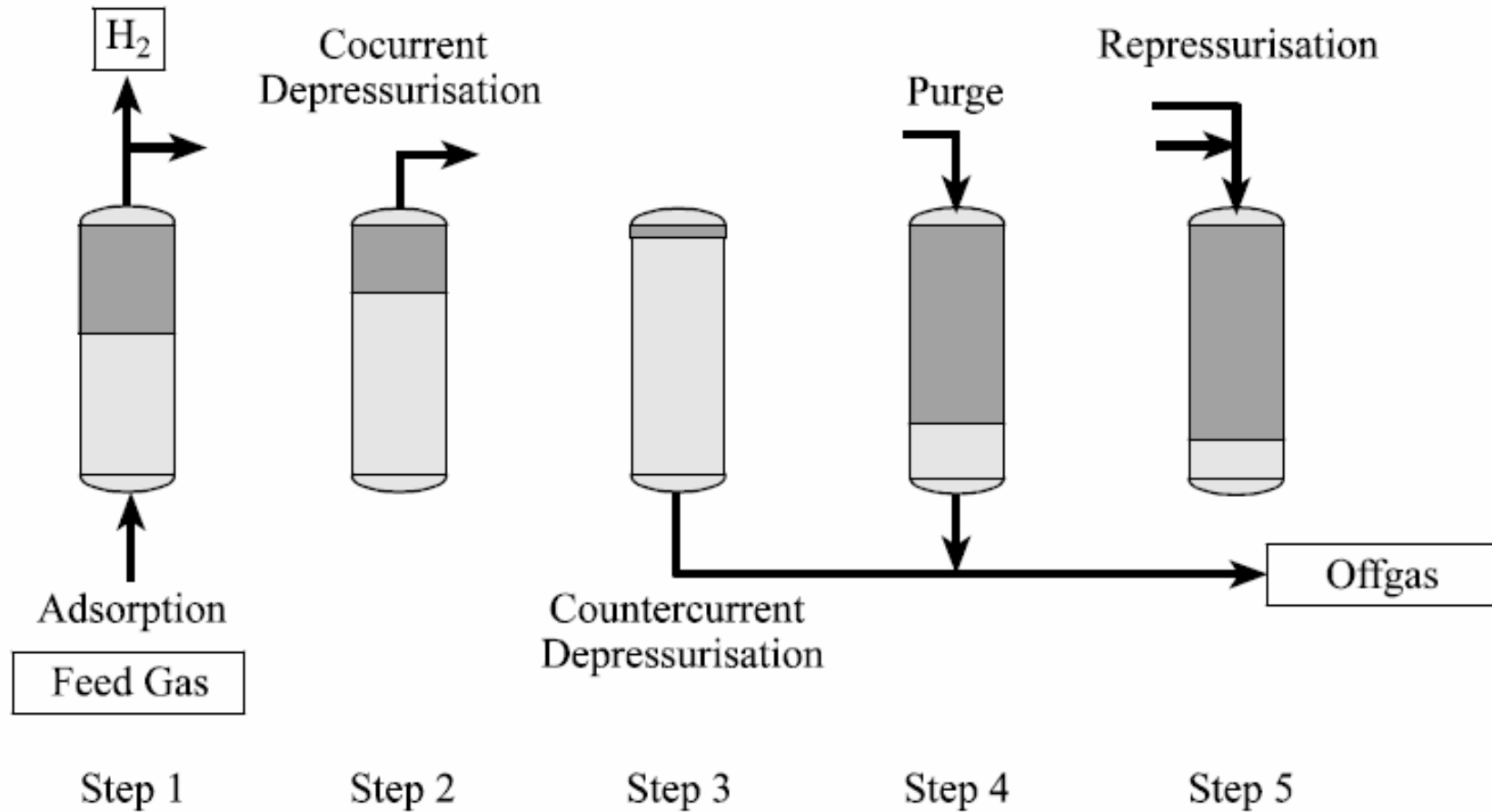
The layered PSA column



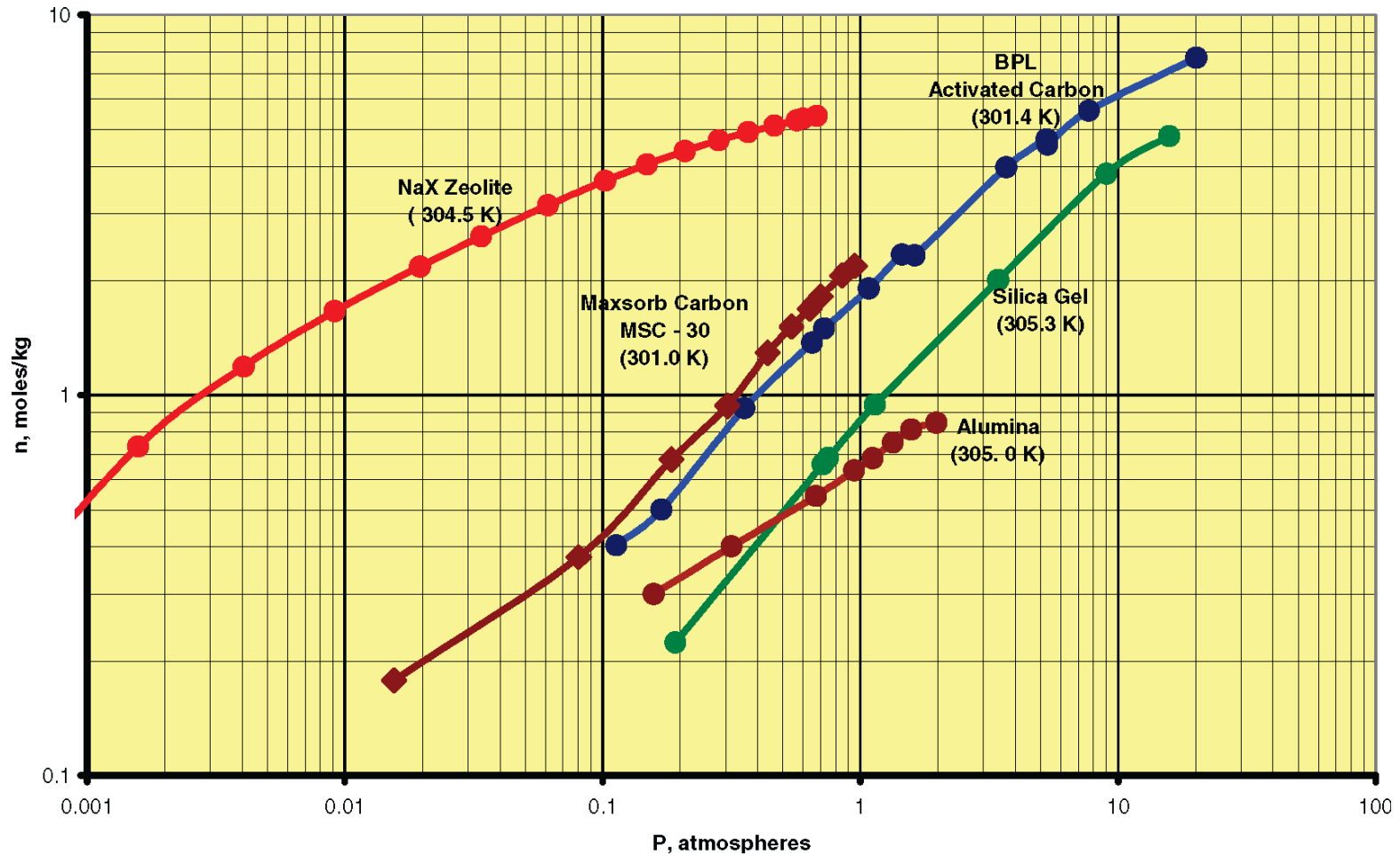
PSA vs TSA (temperature swing)



PSA steps



The PSA adsorbents



The lines are called isotherms

NPRE 470 H2 and Fuel Cells

The PSA Advantages

Simple mechanism

Mature components from CE

Downside: batch type operations

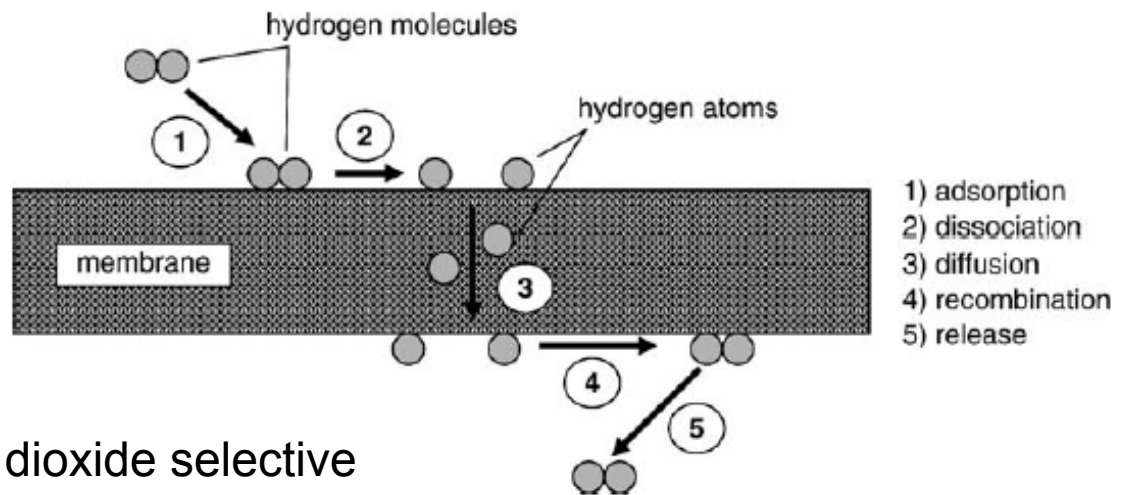
How about separation with membranes?

Membrane H separators

Metal alloy based (Pd..)
Ceramics (gamma-Alumina..)
Polymeric (Polyimide..)

Hydrogen
selective

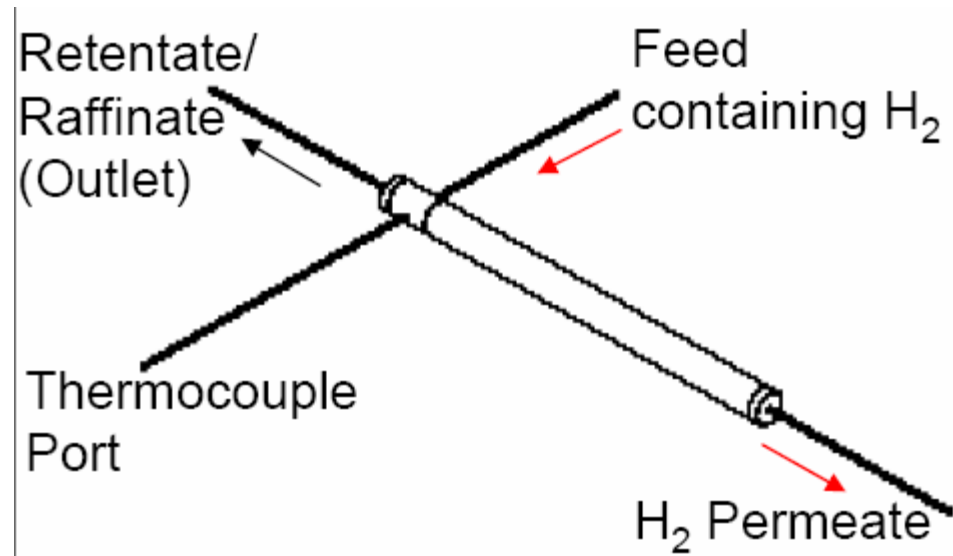
Carbon dioxide
selective



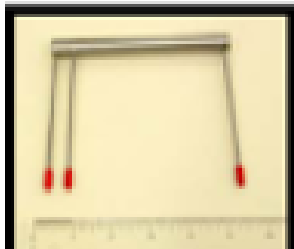
Carbon dioxide selective
(Rubbery type membranes,
poly(ethylene glycol),
Poly(1-trimethylsilyl-1-propyne), PTMSP;
Poly(1-methyl-1-pentyne), PMP;
Poly(tert-butylacetylene), PTBA)

Membrane H₂ separators

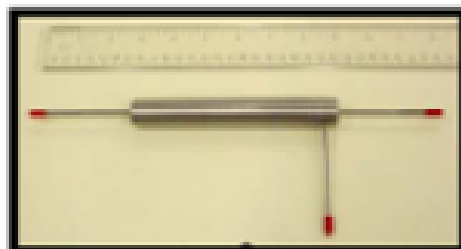
In general, tube like structure to better withstand the pressure.



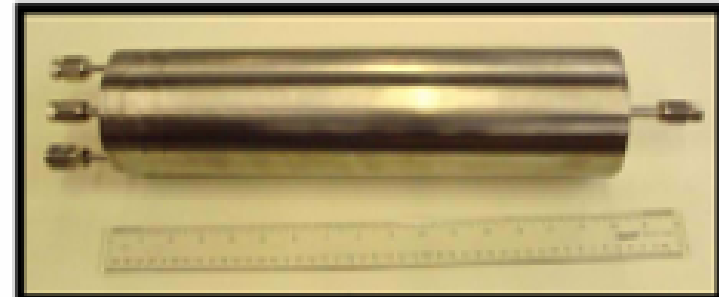
100 Watt
5" x 0.5"



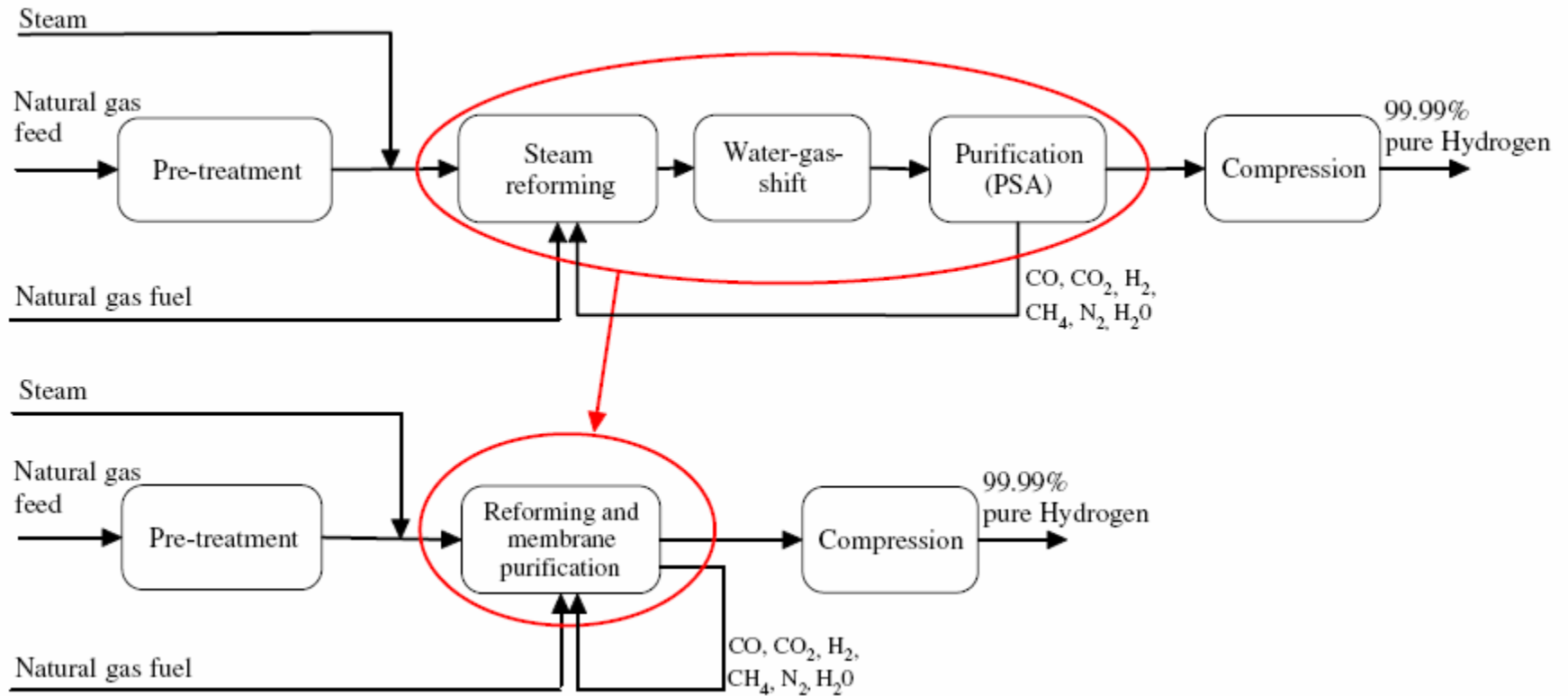
500 Watt
6" x 0.75"



50 kWatt
16" x 4"



Membrane Reactor



Membrane Reactor

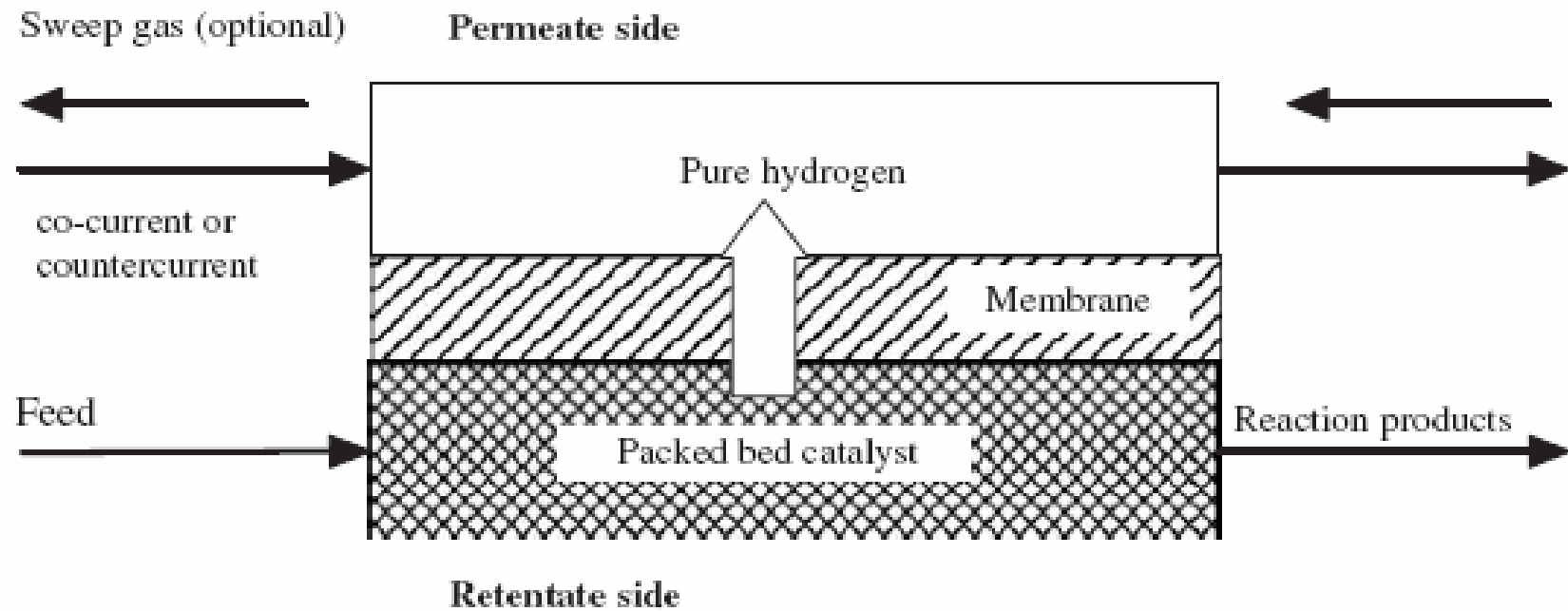


Fig. 2. Principle of the membrane reactor [8].

Principle of operation

NPRE 470 H2 and Fuel Cells

Membrane Reactor

- Limitations
A surface limited process

Maybe when combined with a plasma process it's more efficient?