2024 PSA USERS CONFERENCE

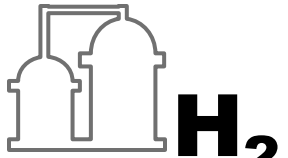
PSA DEBOTTLENECKING GETTING THE MOST OUT OF YOUR ASSETS

ARPIT SHAH
PROJECT DEVELOPMENT MANAGER, UPT HYDROGEN

23 October 2024

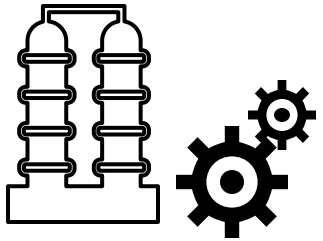
Honeywell
UOP

PRESENTATION OUTLINE



Hydrogen needs of today's refinery

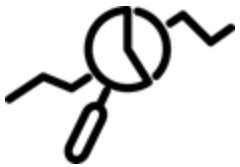
PSA unit components



Increase capacity/ performance of your PSA unit

- UOP High Performance Adsorbents
- Modified PSA Cycles
- PSA Expansions (add vessels)
- Lower Tail Gas Pressure

Case Studies



New Feed Gas Composition & Product Specifications

Reliability enhancement

WHY WORRY ABOUT HYDROGEN?

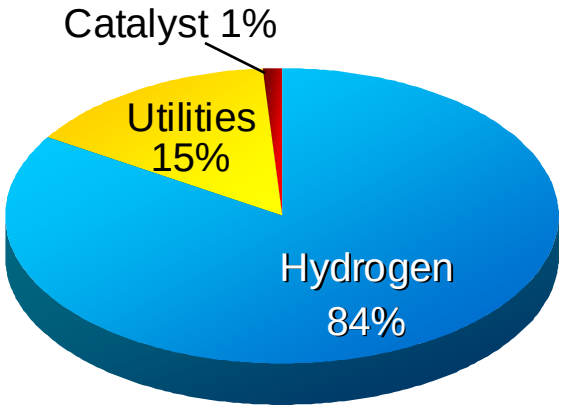
The Obvious Answers

- Demand for low-sulfur fuels
- Heavier crude oil supply
- More conversion

- Lower aromatic gasoline
- H_2 for Fuel Cells

- Need to reduce operating costs
- Minimize CO_2 emissions
  - One ton of H_2 requires 3.5 to 4 tons HC equals to 8 to 12 tons of CO_2

Typical Hydrocracker Operating Costs



Tight Hydrogen Balance Can Constrain Operations

SOURCES OF H_2 IN THE REFINERY

- Catalytic Reforming
- Hydrocracker vents/purges
- Hydrotreater vents
- FCC off-gas/fuel gases

- Steam Methane Reforming

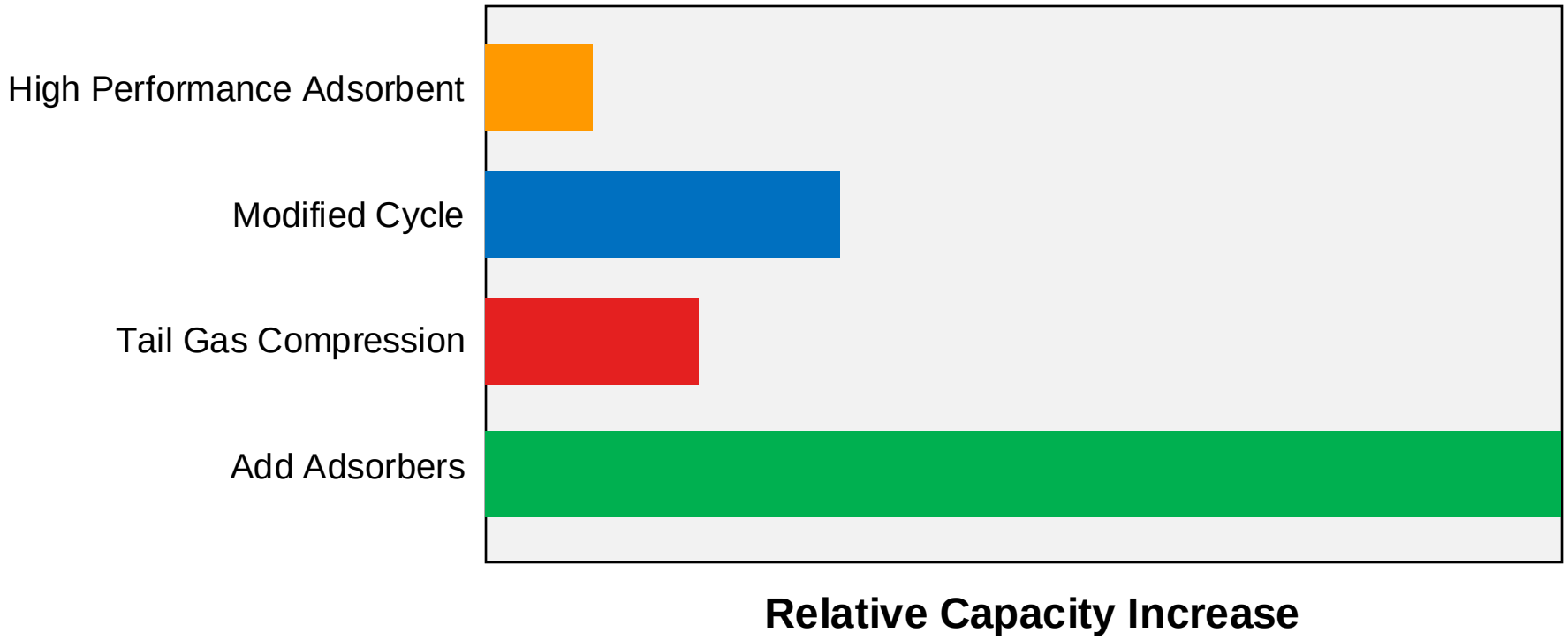
- Petrochemical integration
- Ethylene cracker
- Aromatics plant

Economics of a PSA Unit:

> 50% H_2
40-50% H_2
< 40 % H_2

Pressure and H_2 concentration are key

SOLUTIONS TO INCREASE CAPACITY OF YOUR PSA



Any of the above options can be combined

REVAMP OPTIONS FOR CAPACITY INCREASE

How to increase feed flow rate?

Reduce Subcycle Time

- Run PSA faster
- Modified PSA cycle

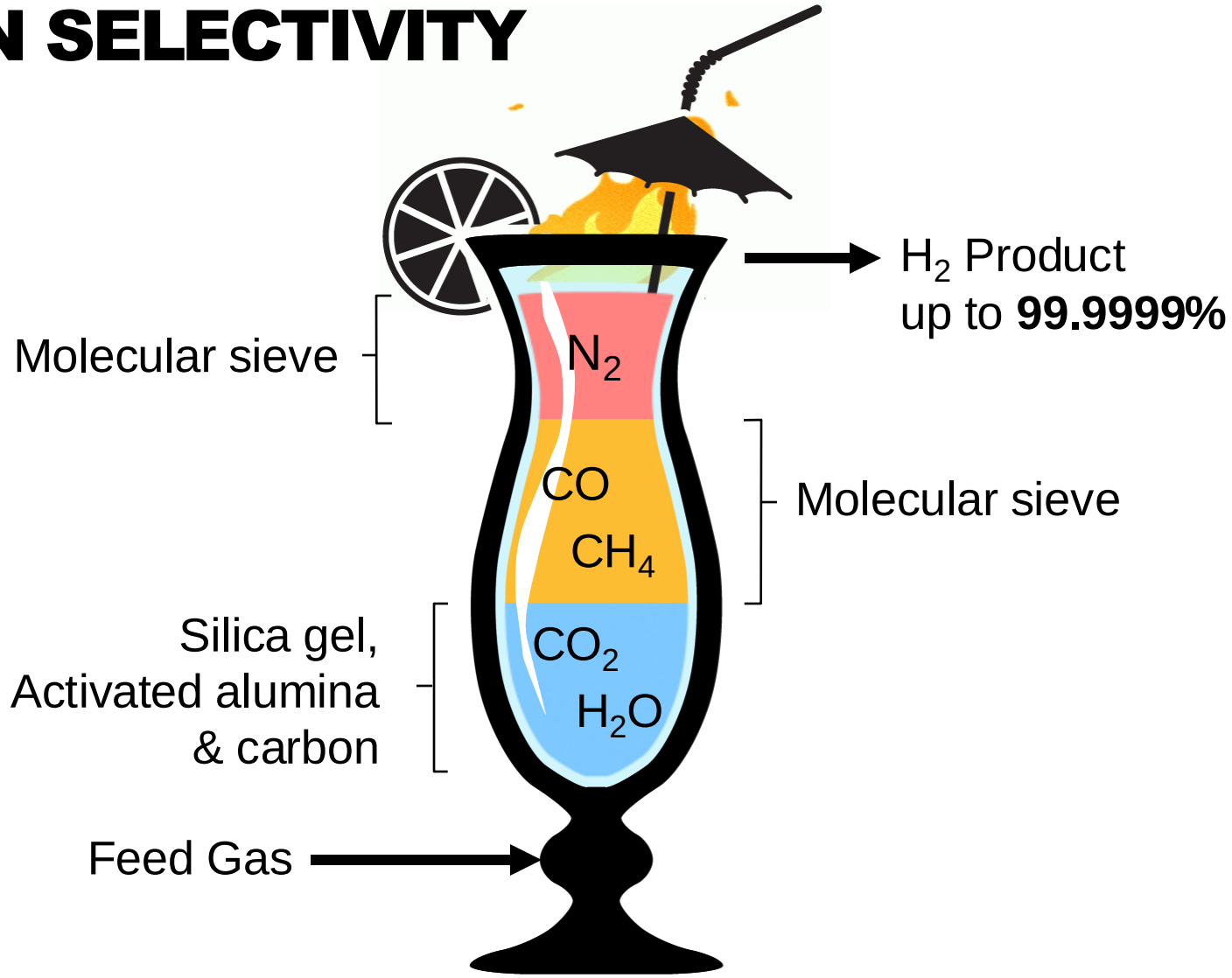
Loading = Feed flow rate x Subcycle Time

Increase Loading

- High Performance Adsorbents

Add more vessels if limit of the cycle time is reached

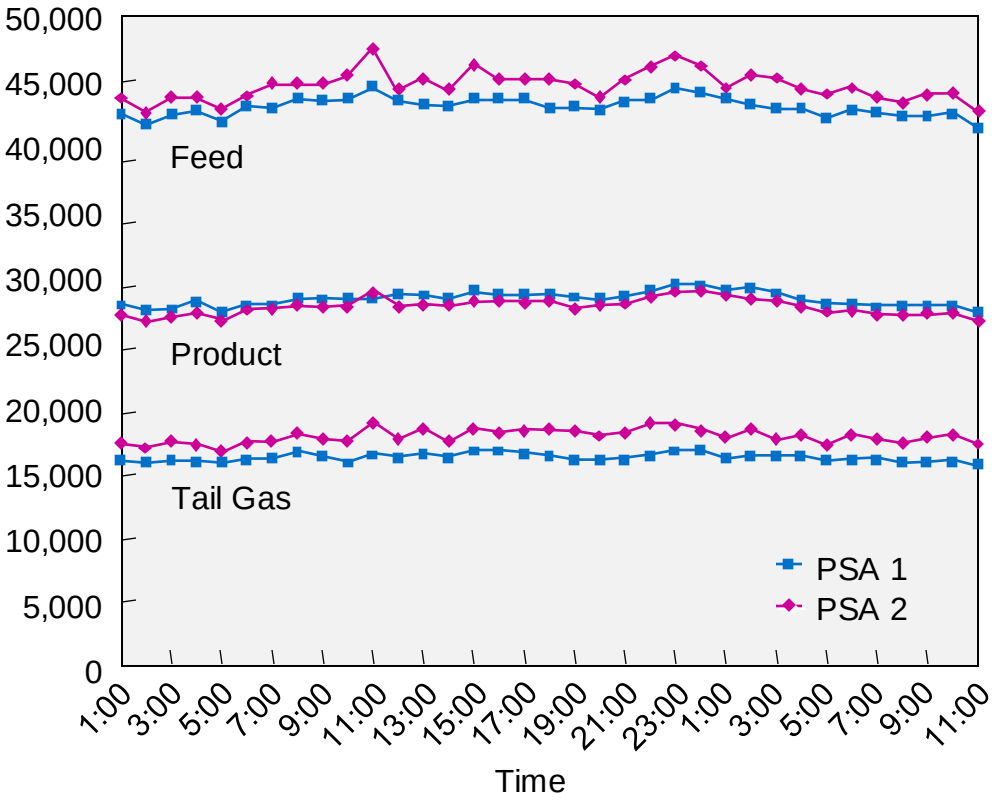
ADSORPTION SELECTIVITY

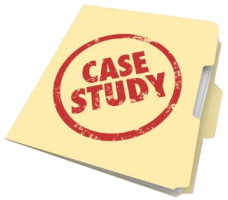


Impurities can be removed to any level required

CASE STUDY 1 – HIGH PERFORMANCE ADSORBENT

Comparison of Two Identical PSA Units Loaded with Different Adsorbents





- With high-performance adsorbents, PSA1 takes **less** feed gas to make practically the same hydrogen production
- PSA2 takes **more** feed to make the same amount of product, making more tail gas

This results in a 2% increase in H_2 recovery. An additional capacity increase was possible in conjunction with this change

SOLUTION 1
HIGH-PERFORMANCE ADSORBENTS WITH CASE STUDY

PERFORMANCE IMPROVEMENT

	Standard Adsorbents	High Performance Adsorbents
Hydrogen Recovery	Base	+2%
Capacity	Base	+15%

Steam reformer applications (SMR)

- Higher recovery/capacity
- Improved CO / N_2 removal
- Tighter H_2 Product specifications

Refinery off-gas applications (ROG)

- Higher recovery/capacity

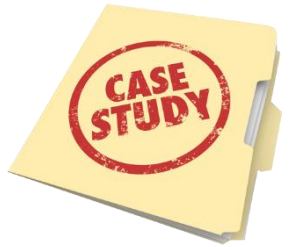
Mandatory Vessel inspections

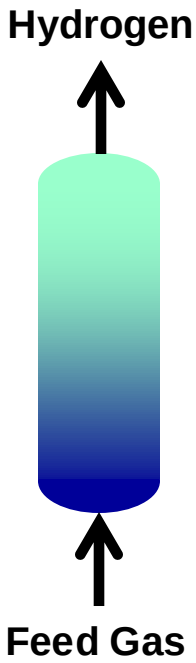
- Check if an adsorbent upgrade is possible

SOLUTION 2
MODIFIED CYCLES TO DEBOTTLENECK PSA UNITS

- Modified Internal Process Steps
- Shorter Adsorption Times
- Trade Recovery for Higher Capacity
- May Require Skid/Valve Modifications
- Switchovers to be Checked

CASE STUDY 2
CAPACITY INCREASE: FASTER CYCLE BY PROGRAMMING UPGRADE



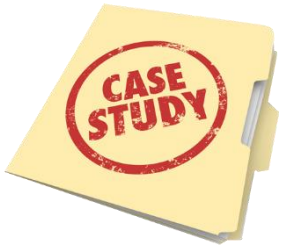


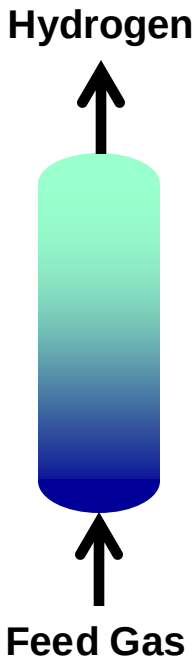
	Base	New Cycle
Bed Volume (m^3)	15	15
Capacity (Nm^3/h)	18,000	24,000
Sub-cycle time (sec)	120	90
H_2 Recovery	86%	84%

+33%

Revamp available for older PSA designs

CASE STUDY 3
CAPACITY INCREASE: MODIFIED CYCLE

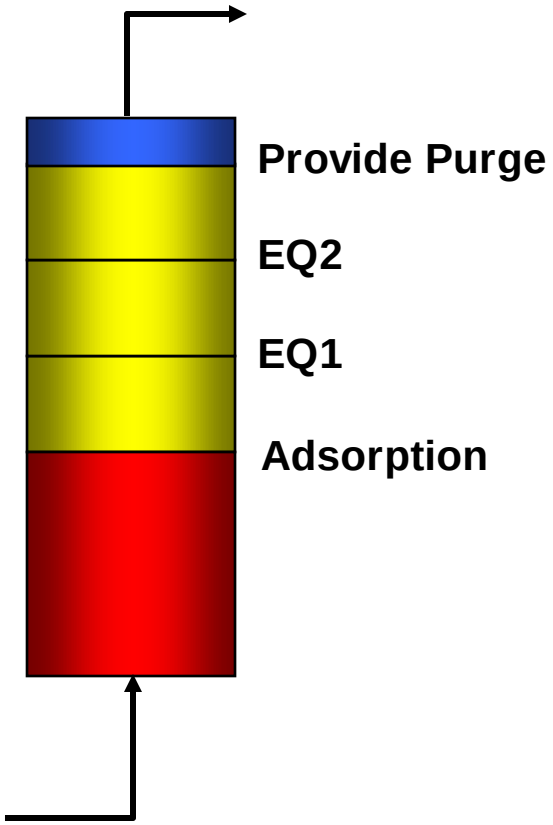


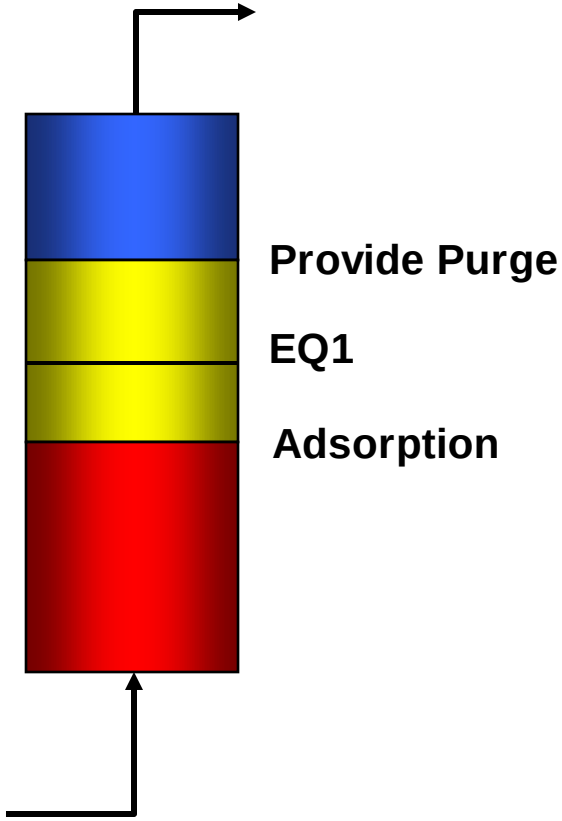


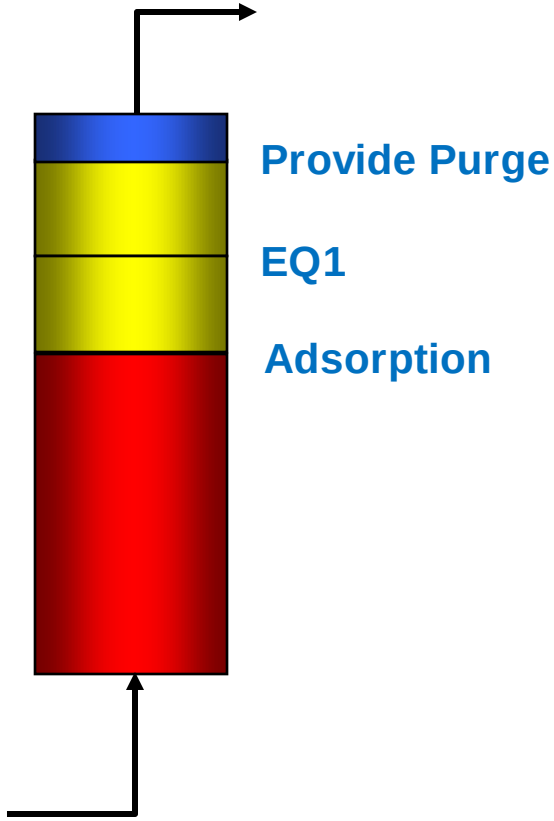
	Base	Modified Cycle
Bed Volume (m^3)	15	15
Capacity (Nm^3/h)	18,000	28,000
Sub-cycle time (sec)	120	75
H_2 Recovery	86%	84%

Trade recovery for capacity

CAPACITY INCREASE
TRADE RECOVERY FOR CAPACITY WITH CASE STUDY



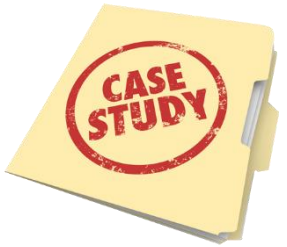




Original Design with 2 Equalization Steps

Revamp - Fewer equalizations results in more feed (adsorption) capacity

CASE STUDY 4 – TRADE CAPACITY FOR RECOVERY



Orig. Design H_2 Prod. 93,000 Nm^3/h, recovery= 89%

Revamped with two operating modes

Winter: H_2 Prod. **93,000 Nm^3/h**, recovery is **89%**
Summer: H_2 Prod. **107,000 Nm^3/h,** recovery is **86%**

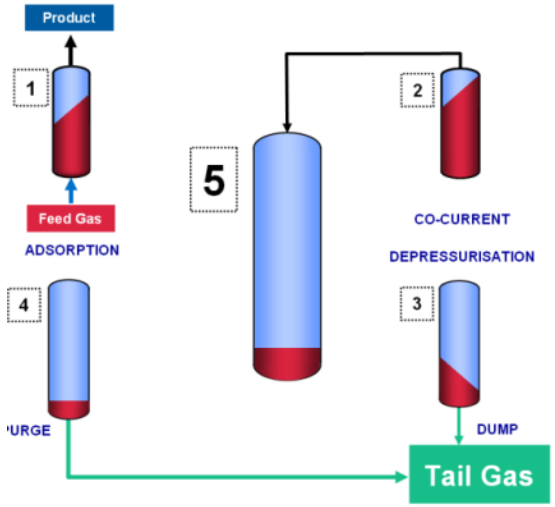
Flexible: Recovery or Capacity

SOLUTION 3
MORE VESSELS (MORE CAPACITY) WITH CASE STUDIES

- Modification of **internal** process steps
- Reduction of adsorption time
- Split regeneration over more adsorbers

Loading = Feed flow rate x Subcycle Time

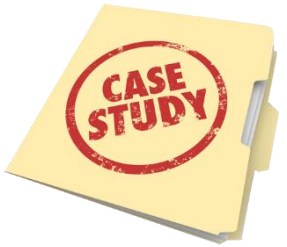
- Hydraulics must be verified
  - Line velocities
  - Valve sizing
  - Bed lifting & flow distribution
  - Switchover mode capacity



CASE STUDY 5 – MORE VESSELS

Steam Reformer PSA Revamp

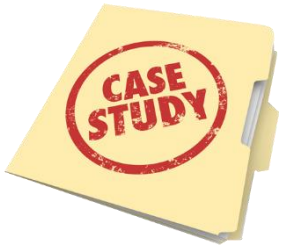
	Original Design	First Revamp
PSA Type	5 Bed	6 Bed
Feed	14,000 Nm^3/h	17,400 Nm^3/h
Product	8,900 Nm^3/h 10 ppm CO	10,700 Nm^3/h 10 ppm CO
Off-Gas	0.35 bar(g)	0.35 bar(g)
Recovery	83%	85%



Cycle Changes: More EQs, shorter cycle time

CASE STUDY 5 – MORE VESSELS & HP ADSORBENT

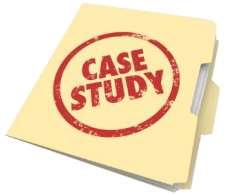
Steam Reformer PSA Revamp



	Original Design	Second Revamp
PSA Type	6 Bed	6 Bed
Feed	17,400 Nm3/h	19,400 Nm3/h
Product	10,700 Nm3/h 10 ppm CO	12,500 Nm3/h 10 ppm CO
Off-Gas	0.35 bar(g)	0.35 bar(g)
Recovery	85%	86%

Add HP adsorbents

CASE STUDY 6: CAPACITY EXPANSION OF LARGE PSA UNIT



Original Design (2006)

- 12-bed PSA Unit
- SMR feed
- High-Performance Adsorbents
- 90% H_2 Recovery
- 150,000 Nm^3/h feed gas
- 99,000 Nm^3/h H_2 product
- Programmed in customer's DCS

Revamp Requirements (2012)

- SMR revamp
- 20% capacity increase
- Maintain 90% H2 Recovery
- Maintain High-Performance Adsorbents

Revamp Options

Option 1: 12-bed, 20% faster cycles

- Valve limitations on PP valves
- Unable to complete all EQ steps
- Unable to maintain 90% recovery
- **NOT POSSIBLE**

Option 2: 14-bed, optimized cycle

- More time available for adsorption and purge
- Optimize pressure profile for 14-bed operation to maintain 90% recovery
- New 14-bed PSA cycle
- Addition of 2 adsorbers + skid + adsorbent + I/O cards
- Keep existing adsorbent in 12 beds
- New PSA Sequence to be programmed in DCS

SOLUTION 4 – LOWER TAIL GAS PRESSURE

Increased Capacity (SMR)

- 0.35 bar(g) tail gas, low-pressure burners only small improvements are possible

Other Applications (Ethylene & Refinery Off-Gas)

- Install tail gas compressor to increase recovery and capacity
- From 4 bar(g) to 0.35 bar(g) expect increase of 12-15% recovery and 25-70% capacity

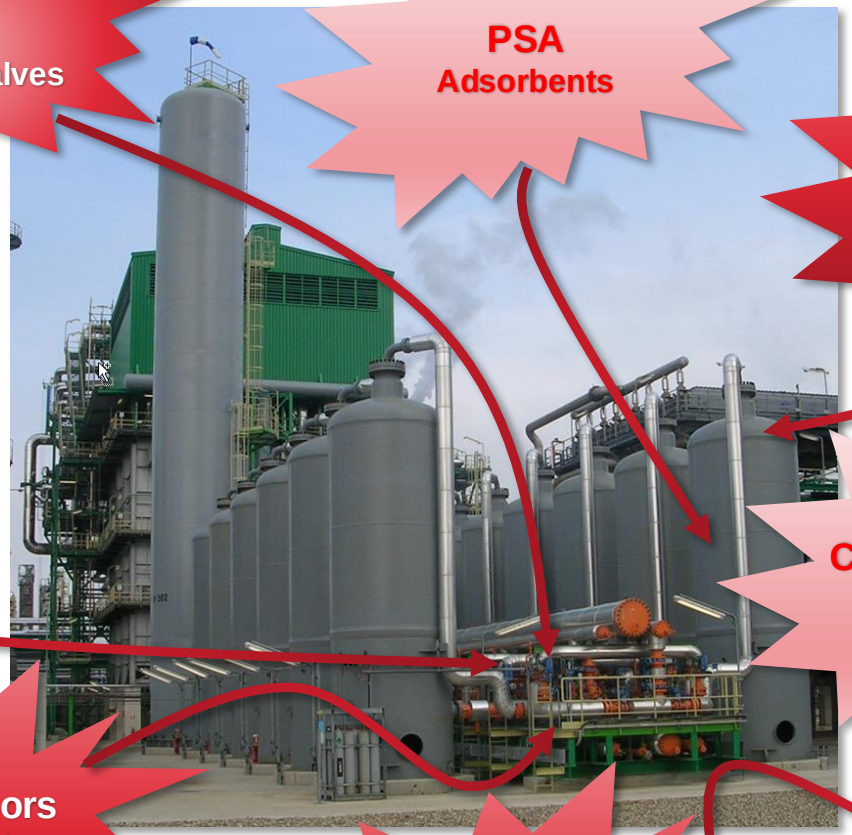
UPDATE PSA TO MEET YOUR CURRENT DEMAND

PSA
Switching Valves

PSA
Adsorbents

PSA
Adsorber
Internals

PSA
Switching Valves
Accessories



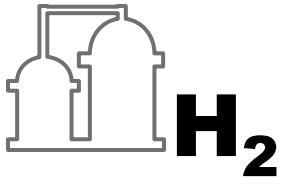
PSA
Control System
PLC / DCS

PSA
Health Check

Human Factors
PSA Skid Design
Accessibility

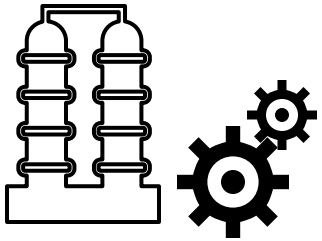
Human Factors
HMI

CONCLUSION



Many cost-effective options to increase H2 production/ availability

Operating flexibility



Maximize use of existing equipment to increase H2 production

Typical revamp schedule < 1 year

Installation typically completed during a two-week turnaround

Revamping is the most cost-effective way to get the most out of your asset

THANK YOU

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