Novel Sulfur Removal Pathways To Aid Energy Reduction and Decarbonization

Who is GTC Vorro . . .

Operating West Texas location

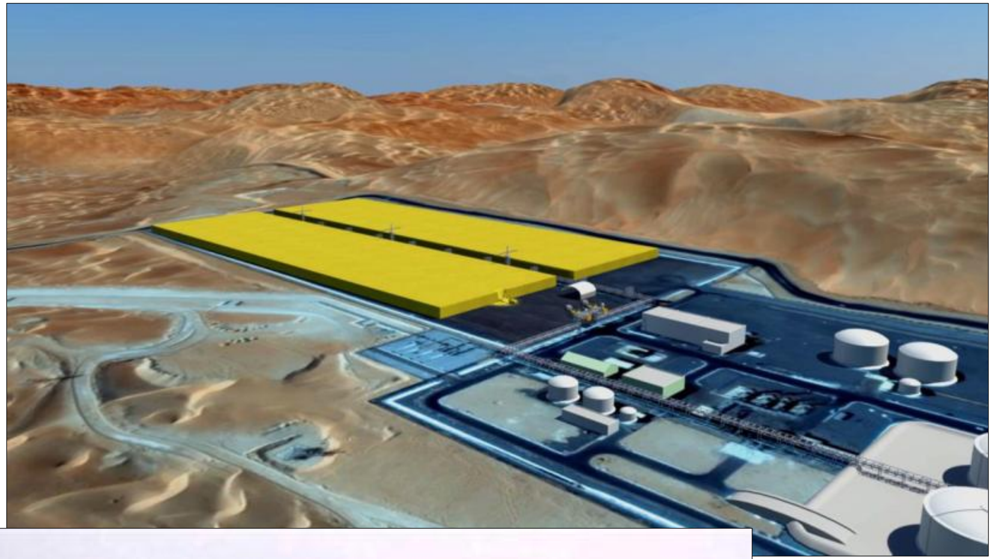
US privately-owned company in business since 2014 based in Houston, Texas, delivering engineered solutions. Two divisions:

- **Environmental Services** Focused on removing harmful H_2S from upstream and midstream natural gas on a turnkey basis. 60 units in operation.
- **Technology Licensing** Focused on
  - Innovative Sulfur Removal Pathways
  - Refining and Petrochemical Technologies
  - Energy Transition: CO_2 utilization and Green H_2

Background

- Sulfur removal traditionally viewed as regulatory compliance implementation

- Development of new media and catalysts have enabled it to be an energy efficiency and decarbonization tool



Webinar Focus

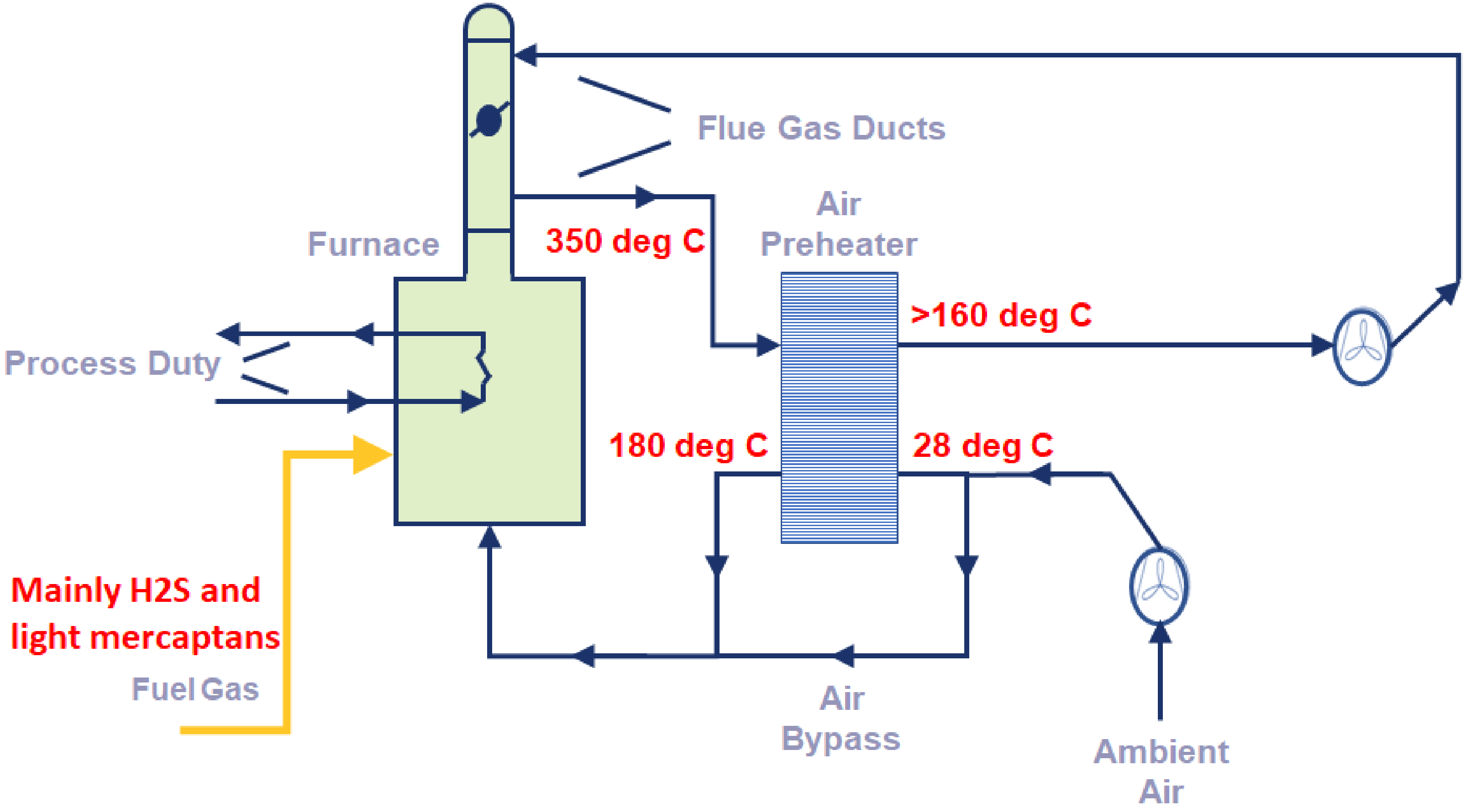
- SweetTreat-O™ : Fuel Gas Sulfur Removal

- NanoSØRB : LPG, FCC Gasoline and Diesel Sulfur Removal:

Fuel Gas

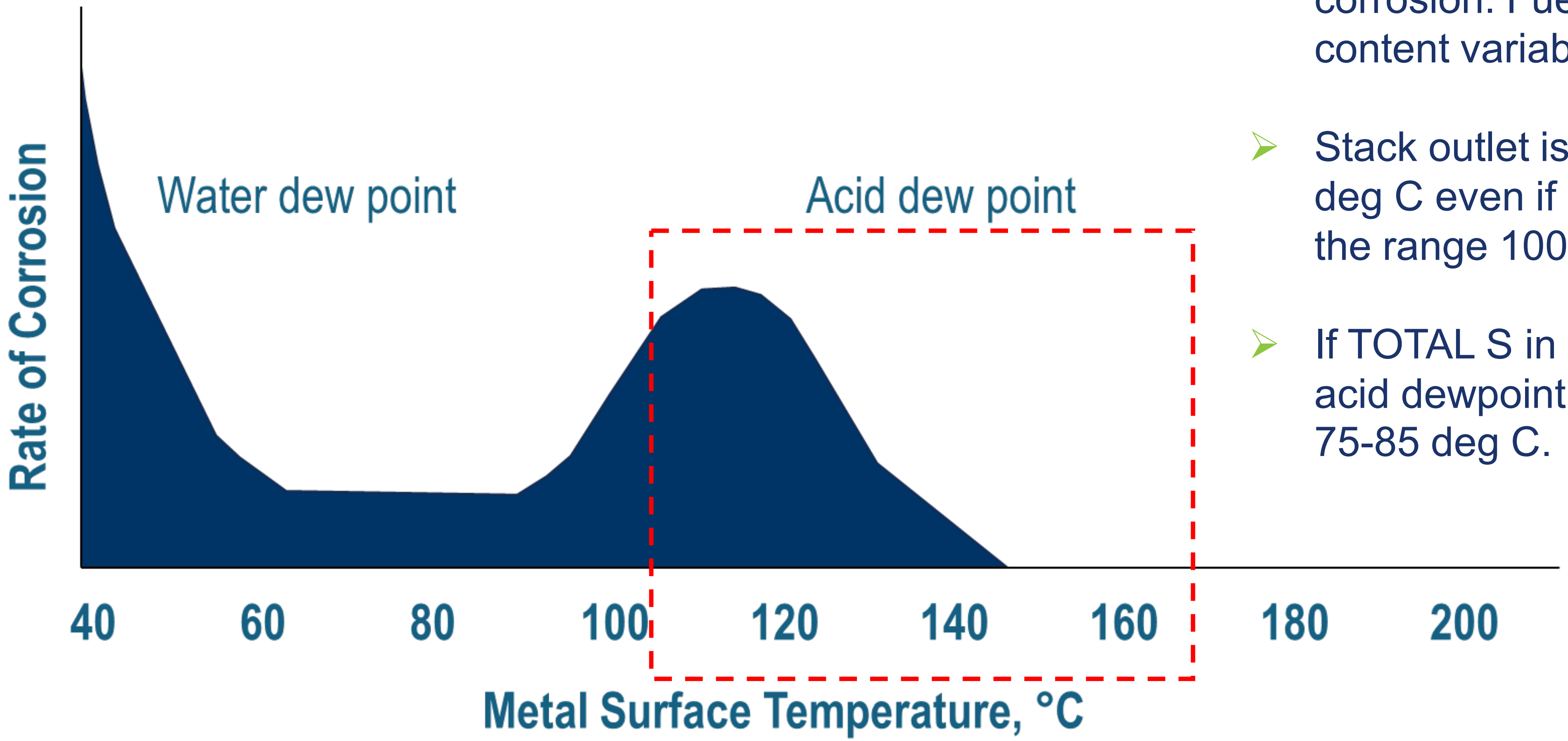
- Typically 20-100 ppm S, controlled by amine system.
- Usually set to meet an overall site emission limit.
- Primary S species: H_2S and light mercaptans.
- Sulfur compounds convert to SO_2 and SO_3. SO_3 reacts with water to form H_2SO_4.
- To avoid condensation, flue stack is kept at elevated temperature.

Example of Air Pre-heater Operation



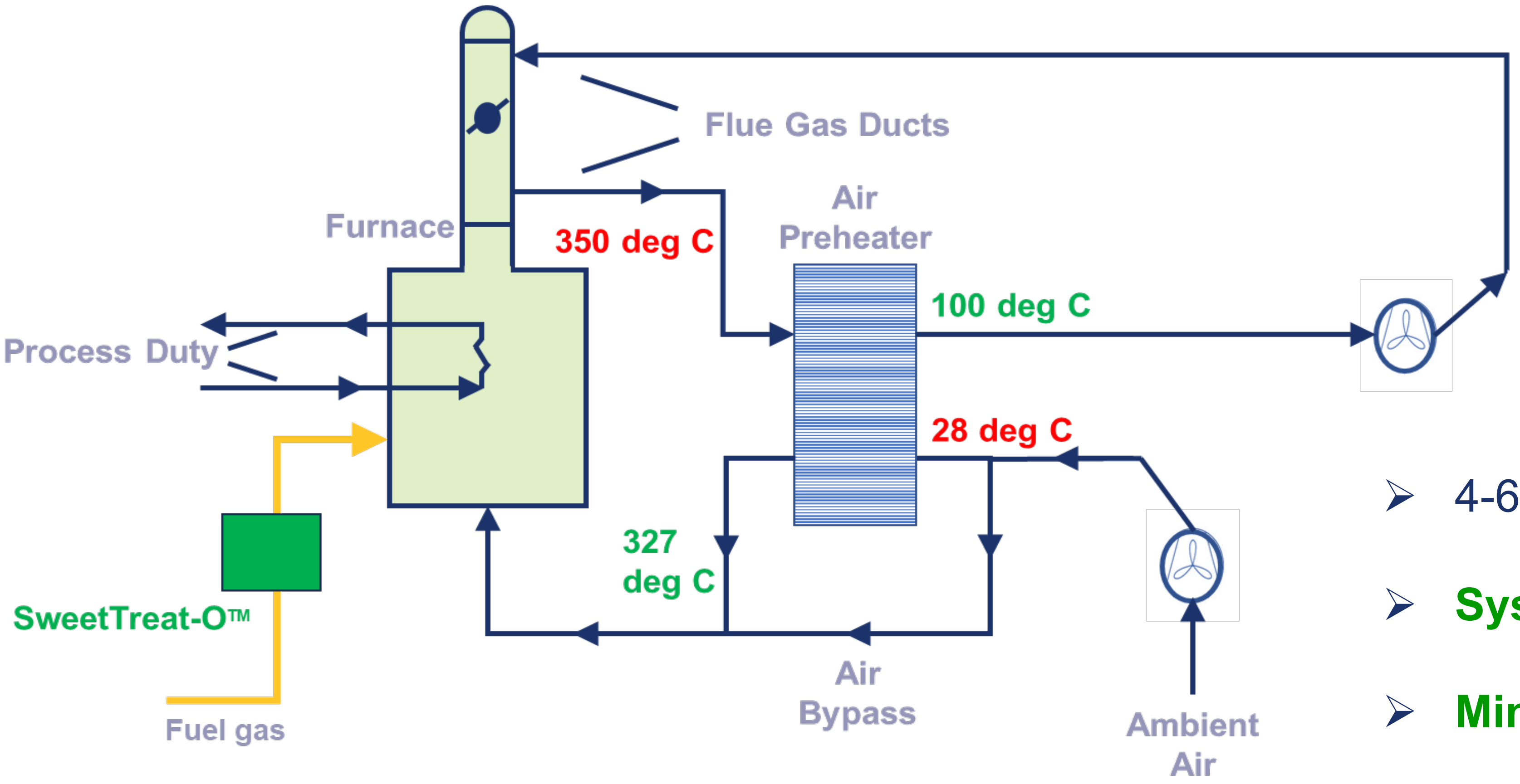
- Robust, but inefficient energy utilization operation due to deliberate high stack outlet temperature.
- 60 deg C window of heat recovery possible across Air Preheater.

Air Pre-heater – Acid Dew Point



- Operator avoids zone of high corrosion. Fuel gas sulfur content variability.
- Stack outlet is maintained >160 deg C even if acid dew point is in the range 100 – 150 deg C.
- If TOTAL S in Fuel gas <1 ppmv, acid dewpoint falls in the range 75-85 deg C.

Air Pre-heater Optimized Operation



- 4-6% overall energy savings
- **System Payback period < 1 year**
- **Minimal CO_2 and SO_2 emissions**

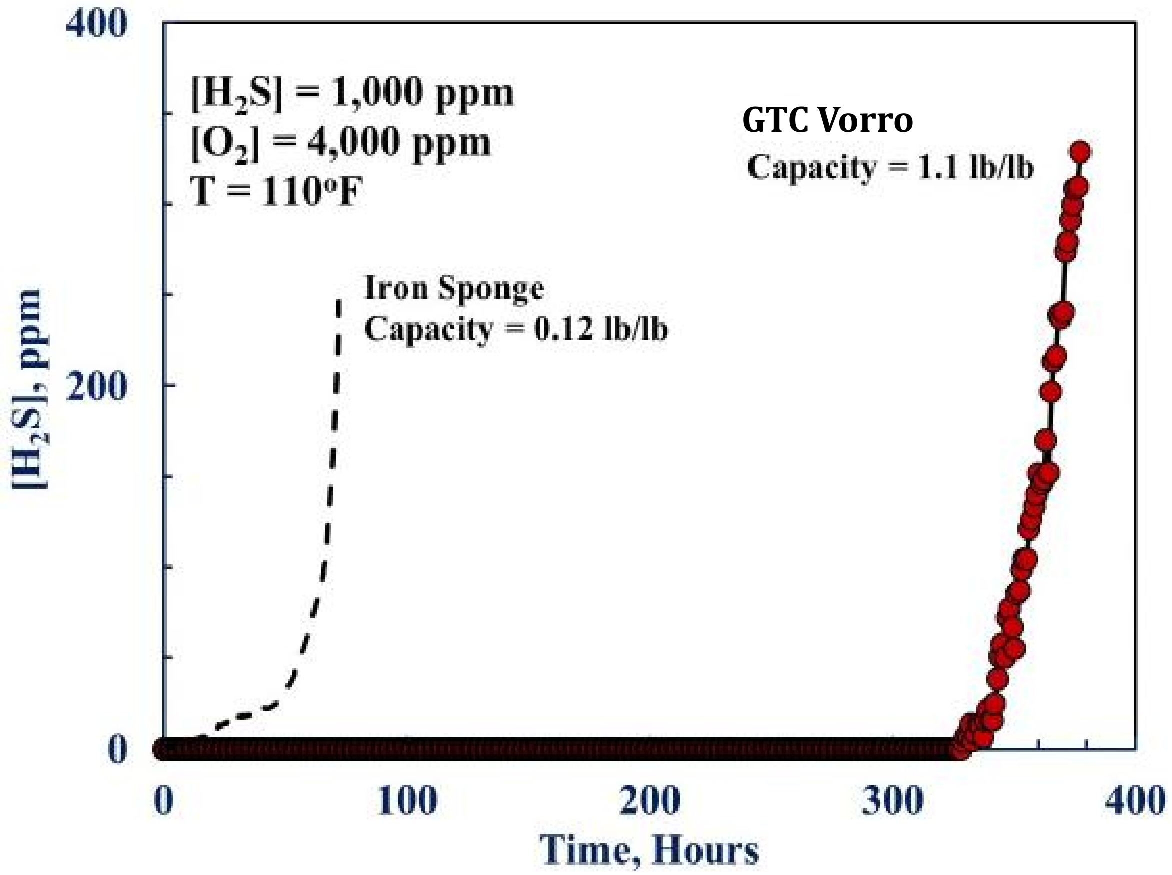
SweetTreat-O™

- Proprietary mixed metal oxide- hydroxide based solid adsorbent for H_2S and light mercaptan removal.
- Exceptionally high H_2S removal capacity: *120 wt% loading!*
- Optimal combination of different media achieves <1 ppmv TOTAL S.
- Expected Acid Dewpoint at <1 ppmv TOTAL S in Fuel Gas: 75-85 deg C.

Minimal Pressure Drop (<2 psi)

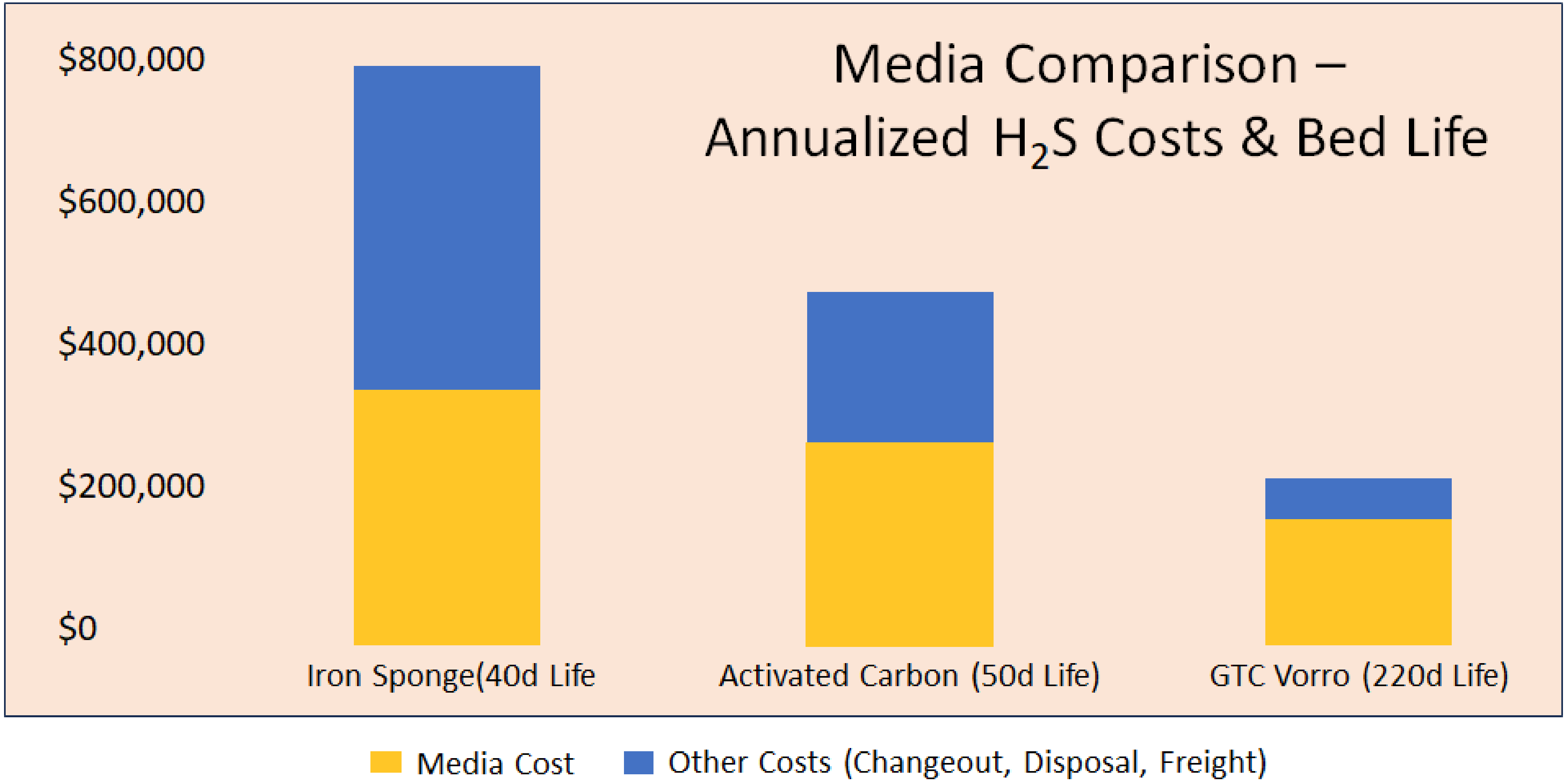
Improved Media

Proprietary Mixed Metal Oxide – hydroxide with high metal content and porous structure.



H_2S Removal – Iron Sponge vs GTC Vorro

Lowest Total Cost for H_2S Removal



GTCV Media: Pressure Drop

- Media has low density (23-26 lb/ft3) and porous structure.
- Sulfur deposits inside the pores, while the gas flows on the outside.
- Fuel Gas systems have limited pressure drop margin. 7-10 psi.
- Media’s unique pore structure results in < 2 psi pressure drop across entire skid at end-of-run.

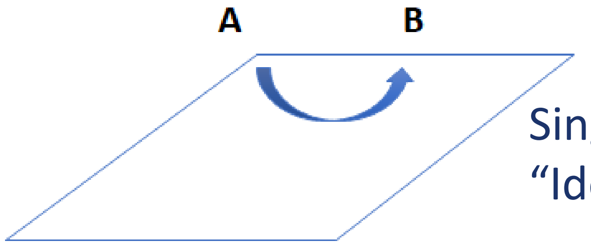
Media Changeout

- Changeout is done via a manhole located on side of the vessel. Media is free-flowing when spent.
- Conventional iron oxide-based media changeouts are difficult and need careful media handling.
- Conventional spent Iron oxide media is pyrophoric, while spent GTCV media is not.
- No need for hydrovaccuming the spent media from top.

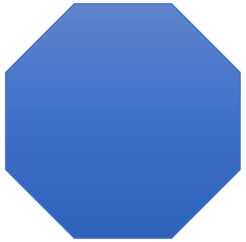
Introducing Catalytic Adsorption: NanoSØRB

- Singular dimension nano-wire technology gives much higher dispersion of metals with improved activity and selectivity.
- Revolutionary improvement compared to current-state-of-the-art.
- Capable of removing H_2S, Mercaptans, Disulfides and Thiophenes.
- Regenerable media. Ideal for fine sulfur removal.

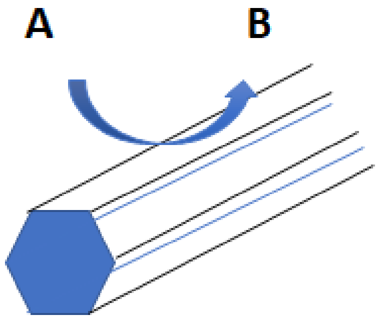
Principles of Nanowire Technology



Single crystal surface
"Ideal"



Traditional catalysts: Spherical particles with many different surfaces "Low reactivity & selectivity"



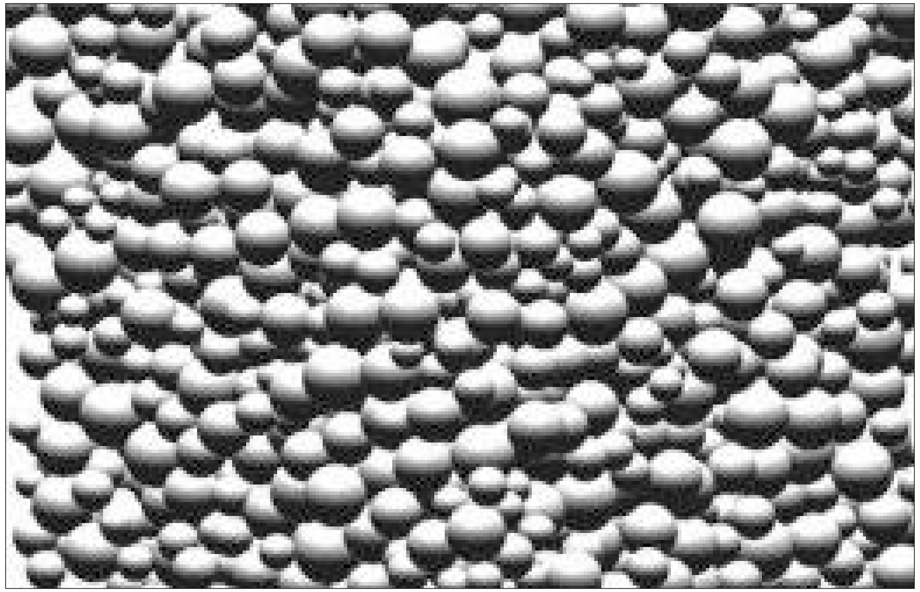
Nanorods:
single crystal surfaces
"high reactivity & selectivity"

Nanowire transforms catalysis

- Ultra-fine dispersion of active metals onto substrate
- Higher activity, selectivity and durability against sintering
- Dual-function: **catalytic** and **adsorptive**. "Chemisorption" or "Catalytic Adsorption"

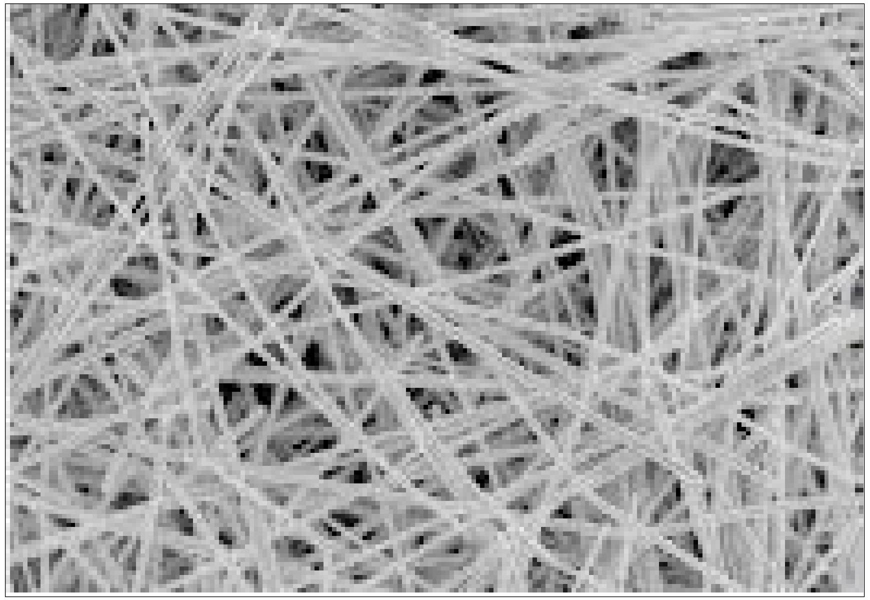
Metals Dispersion

Traditional Metals Deposition



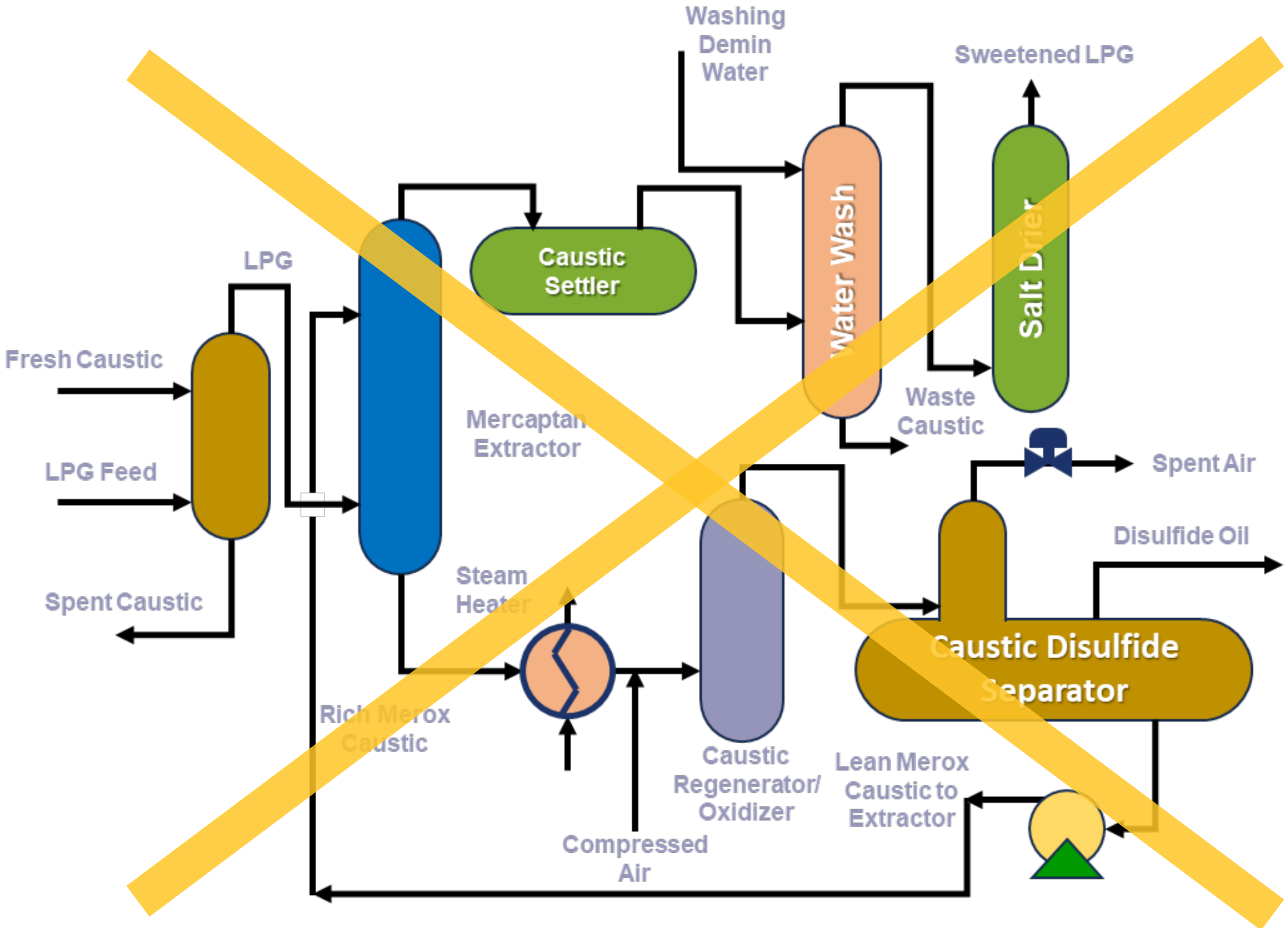
Packing of spherical powders: sinter over time – Lose surface area and activity

Nanowire Structure

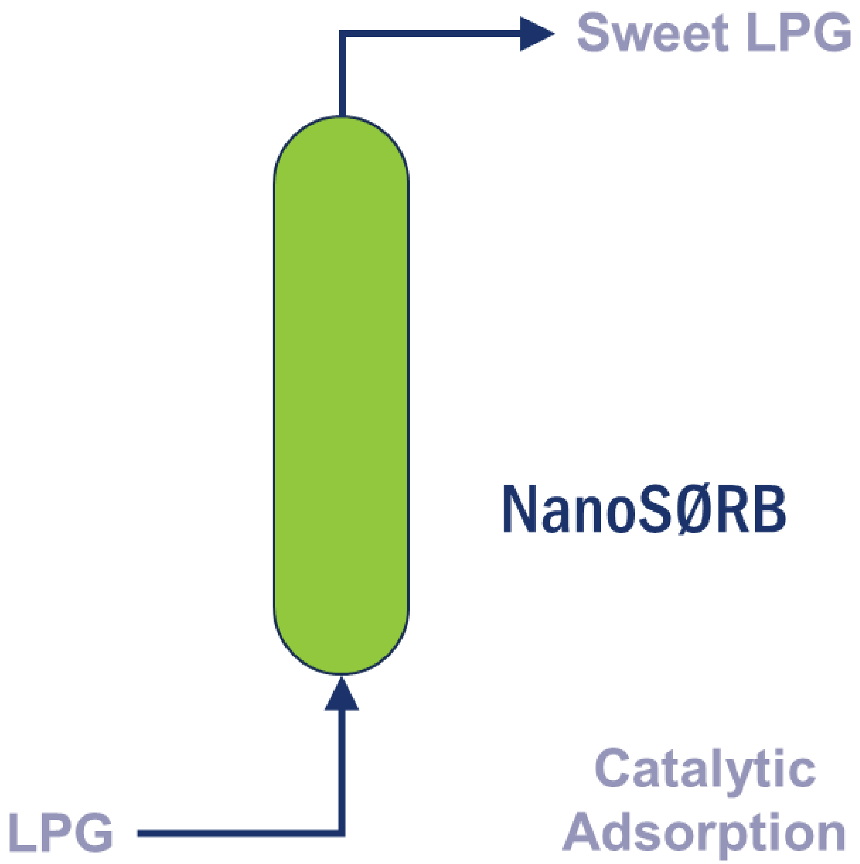


Packing of nanowires: No sintering and loss of area, resulting in higher lifetime

LPG - Caustic Treater Option

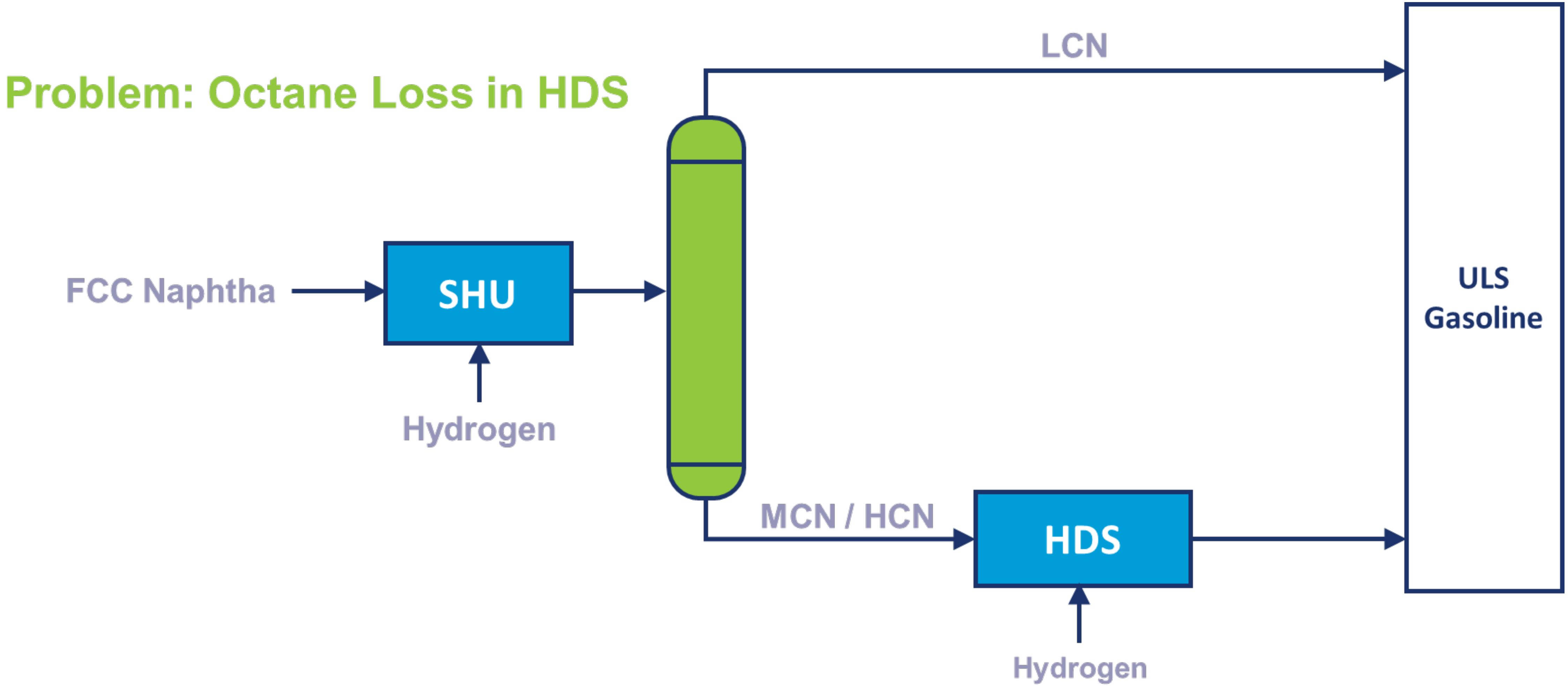


- Fresh Caustic Required
- Continuous Waste



- Regenerable Media
- Eliminates Waste Caustic

FCC Gasoline - Typical Hydrotreating/Desulfurization Process



FCC Gasoline Octane Loss

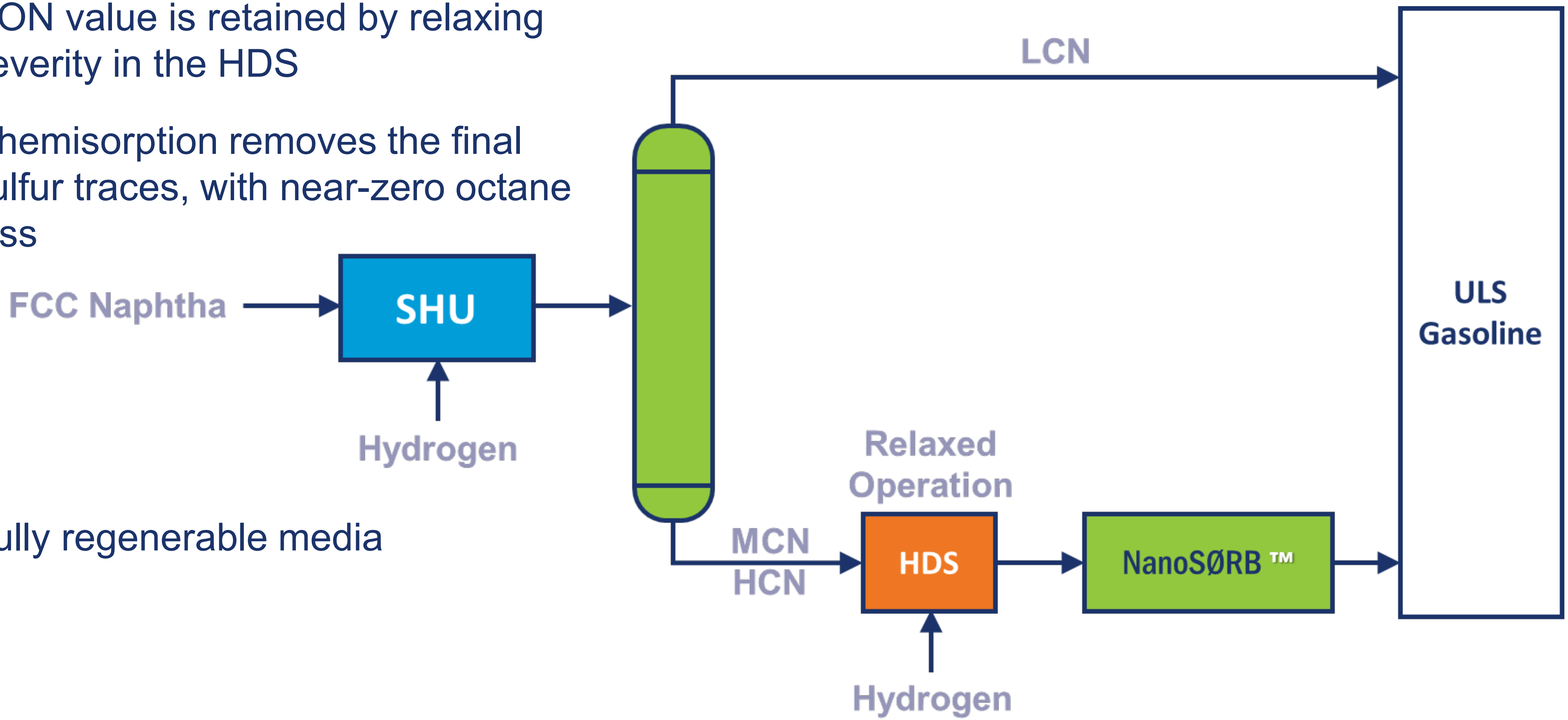
There is inevitable octane loss due to saturation of olefins.

Olefin Saturation is the Problem	
	RON
C – C – C – C – C = C (Hexene)	76
C – C – C – C – C – C (Hexane)	24

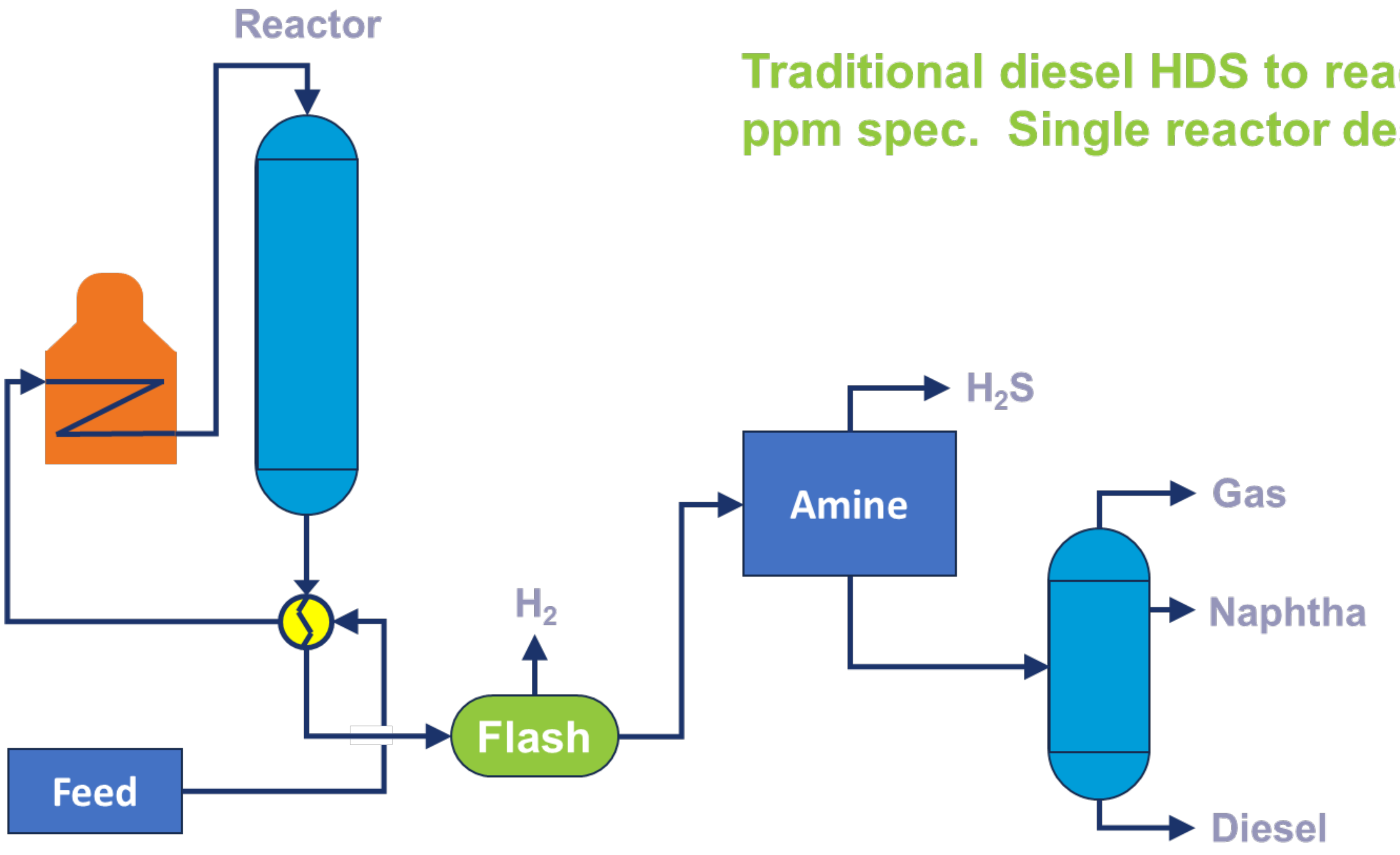
Solution – reduce saturation of olefins by reconfiguring the process

Polishing by Chemisorption

- RON value is retained by relaxing severity in the HDS
- Chemisorption removes the final sulfur traces, with near-zero octane loss
- Fully regenerable media

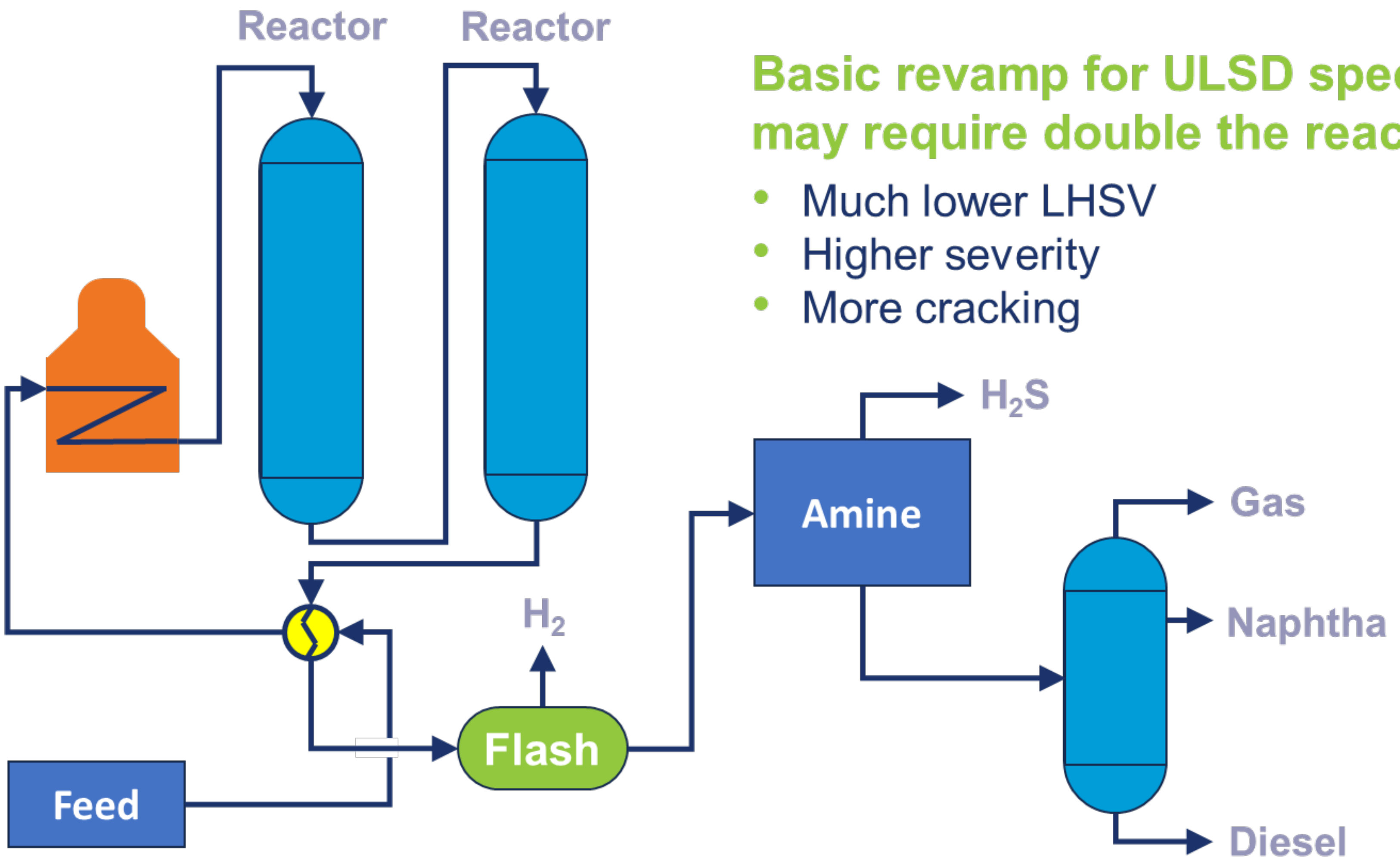


Diesel Desulfurization



Traditional diesel HDS to reach 500 ppm spec. Single reactor design.

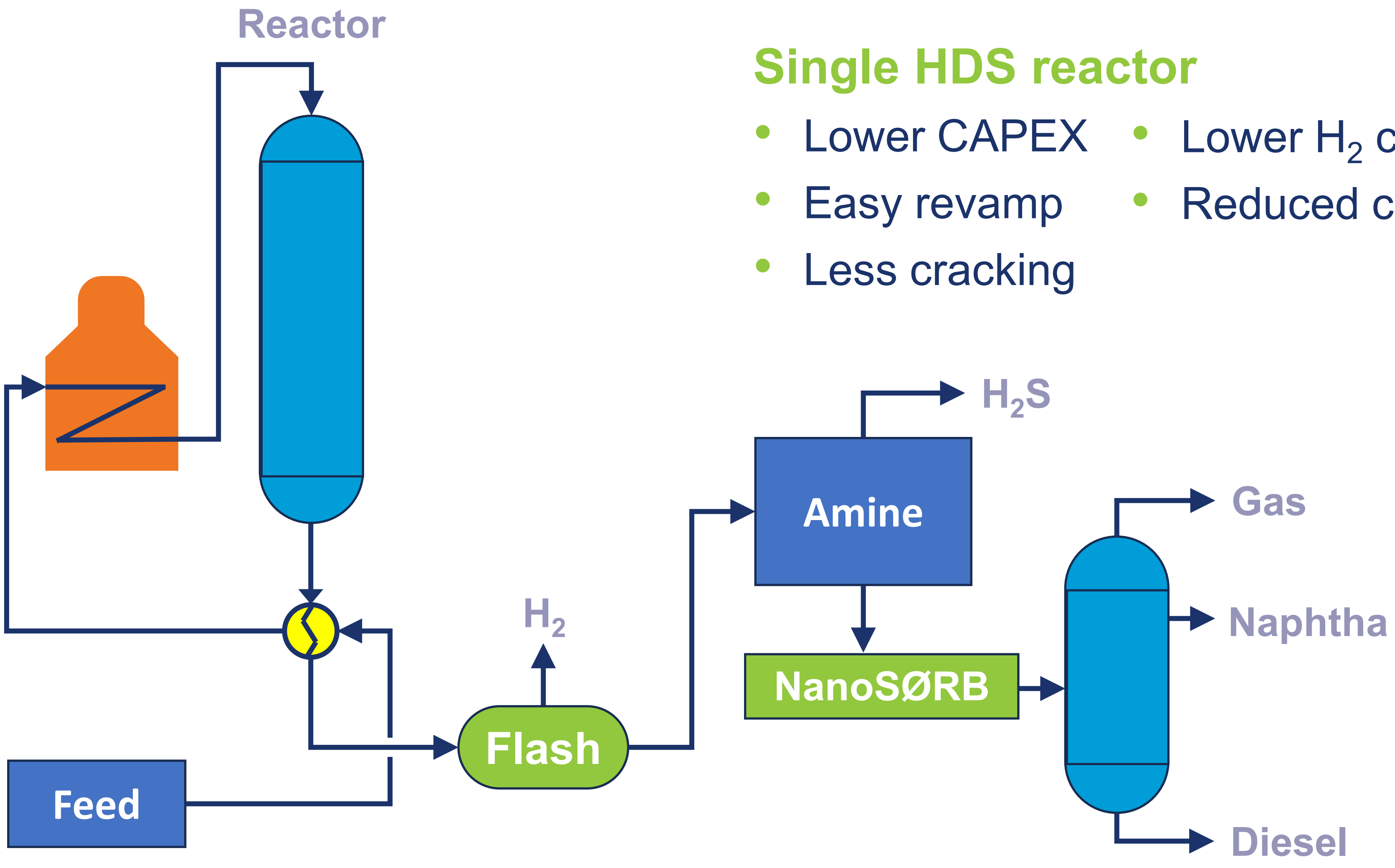
ULSD with New, Full-size Reactor



Basic revamp for ULSD specification, may require double the reactor volume

- Much lower LHSV
- Higher severity
- More cracking

ULSD with Catalytic Adsorption Polishing System



Single HDS reactor

- Lower CAPEX
- Easy revamp
- Less cracking
- Lower H_2 consumption
- Reduced catalyst quantity

Summary

- Development of new media and catalysts opens doors for:
  - SO_2 emissions compliance
  - Achieving higher energy efficiency
  - Decarbonization

- Fuel Gas, LPG, FCC Gasoline and Diesel are ripe candidates to achieve above goals via deployment of SweetTreat-O™and NanoSØRB.

GTC VORRO TECHNOLOGY

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