



**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

Presentation Focus

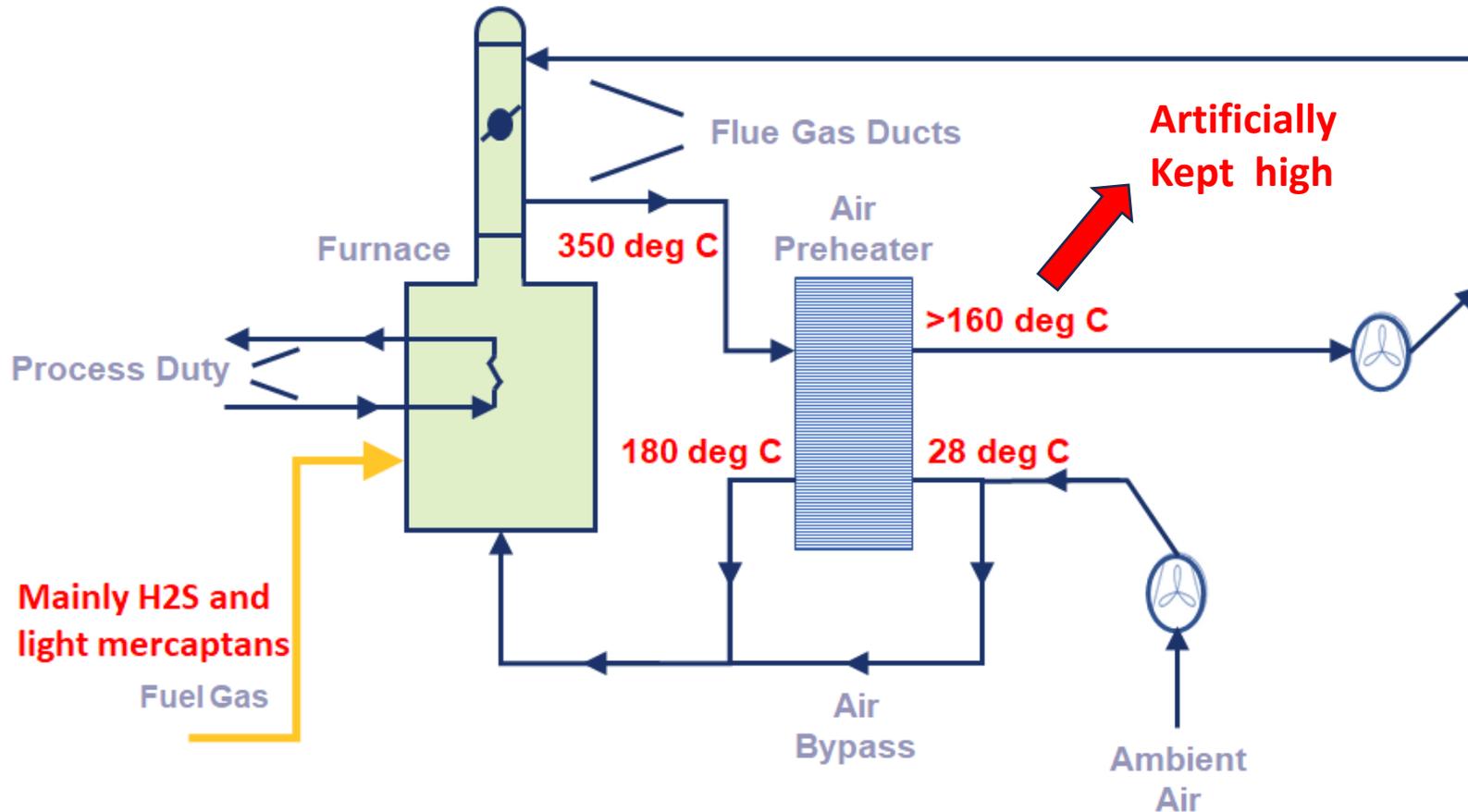
- SweetTreat-O™ : Fuel Gas Sulfur Removal
- NanoSØRB™ : LPG, FCC Gasoline and Diesel Sulfur Removal

Fuel Gas

- Typically 20-100 ppm S, controlled by amine system.
- Usually set to meet an overall site emission limit.
- Primary S species: H₂S and light mercaptans.
- Sulfur compounds convert to SO₂ and SO₃. SO₃ reacts with water to form H₂SO₄.
- To avoid condensation, flue stack is kept at elevated temperature.

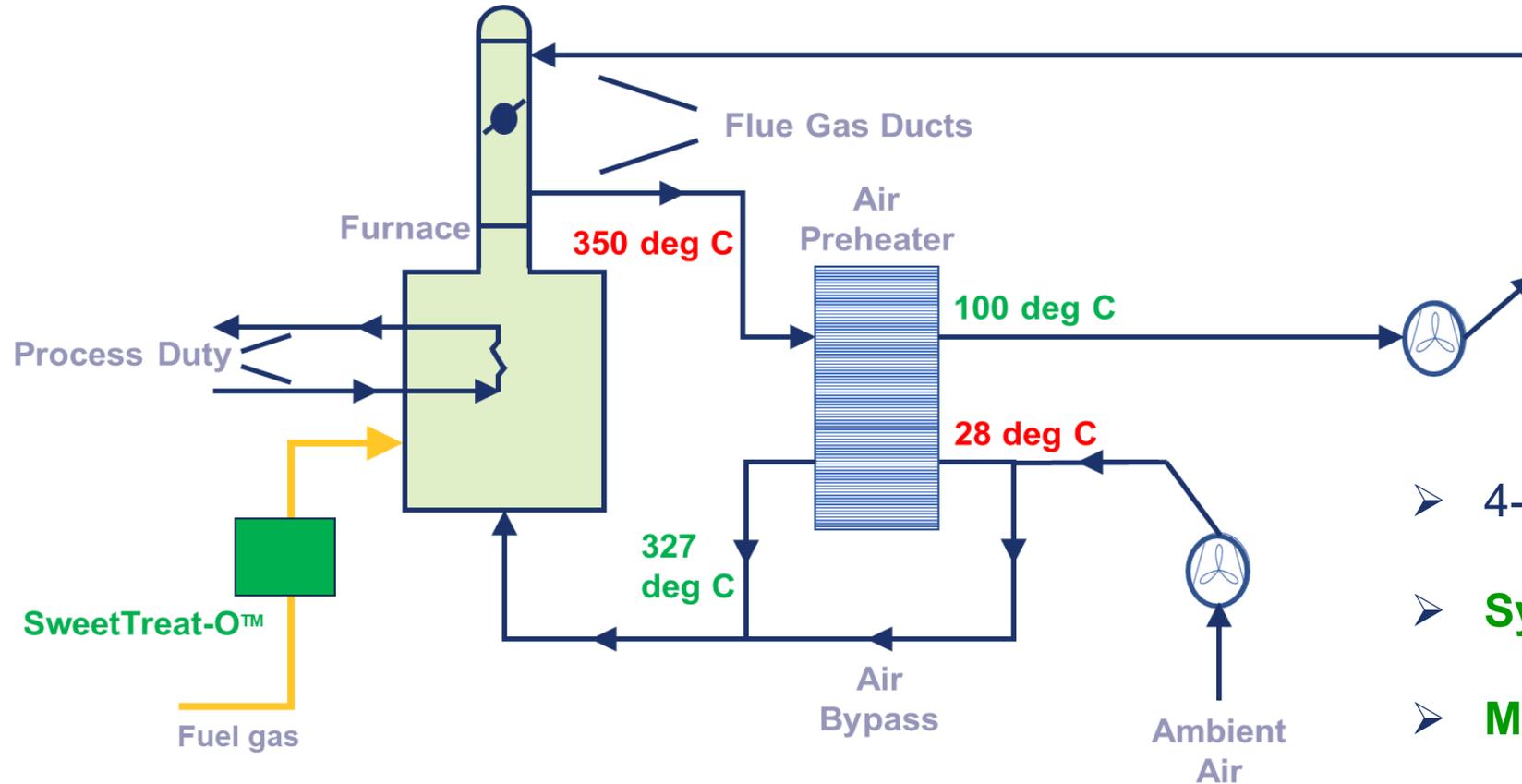


Example of Air Pre-heater Operation



- 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 Optimized Operation



- 4-6% overall energy savings
- **System Payback period < 1 year**
- **Minimal CO₂ and SO₂ emissions**

SweetTreat-0™

- Proprietary mixed metal oxide- hydroxide based solid adsorbent for H₂S and light mercaptan removal.
- Exceptionally high H₂S 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)

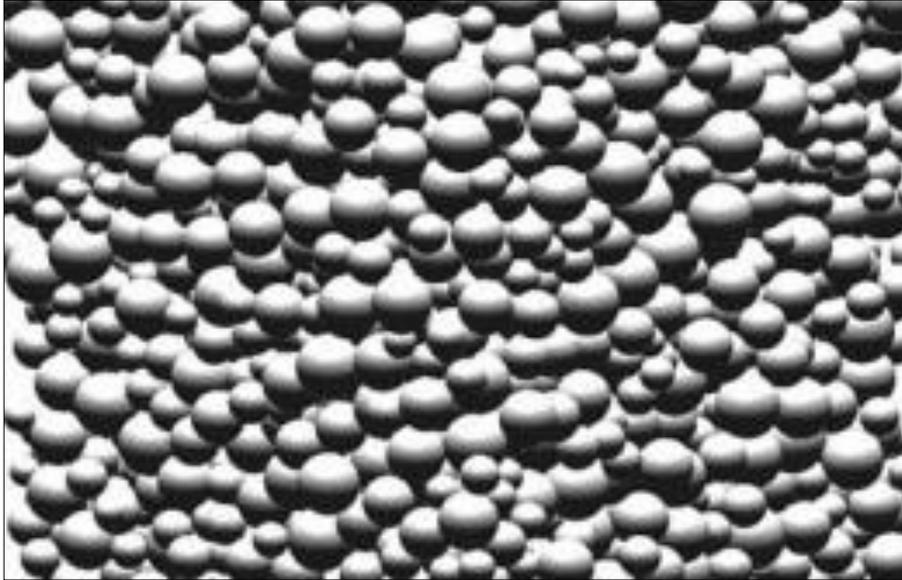
Introducing Catalytic Adsorption: NanoSØRB™

- 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 H₂S, Mercaptans, Disulfides and Thiophenes.
- Regenerable media. Ideal for fine sulfur removal.



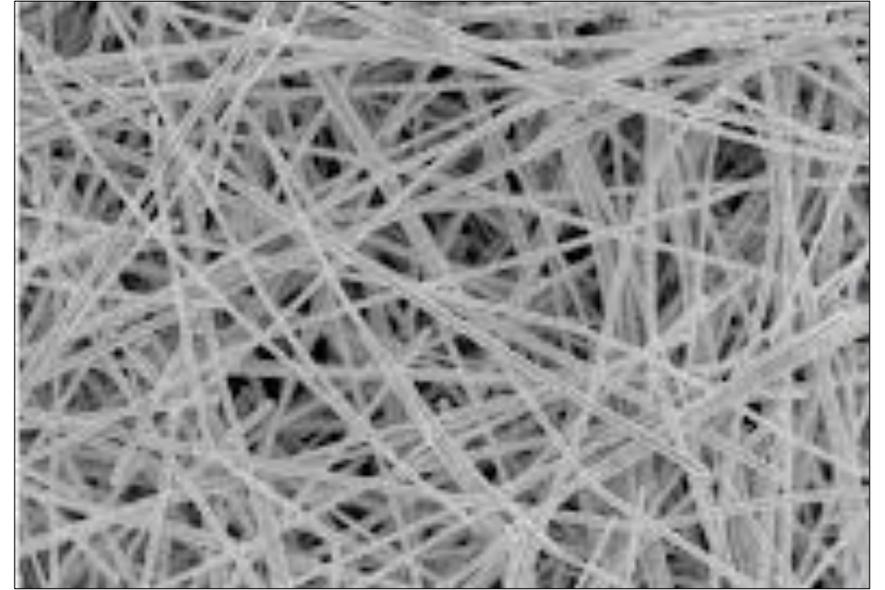
Metals Dispersion

Traditional Metals Deposition



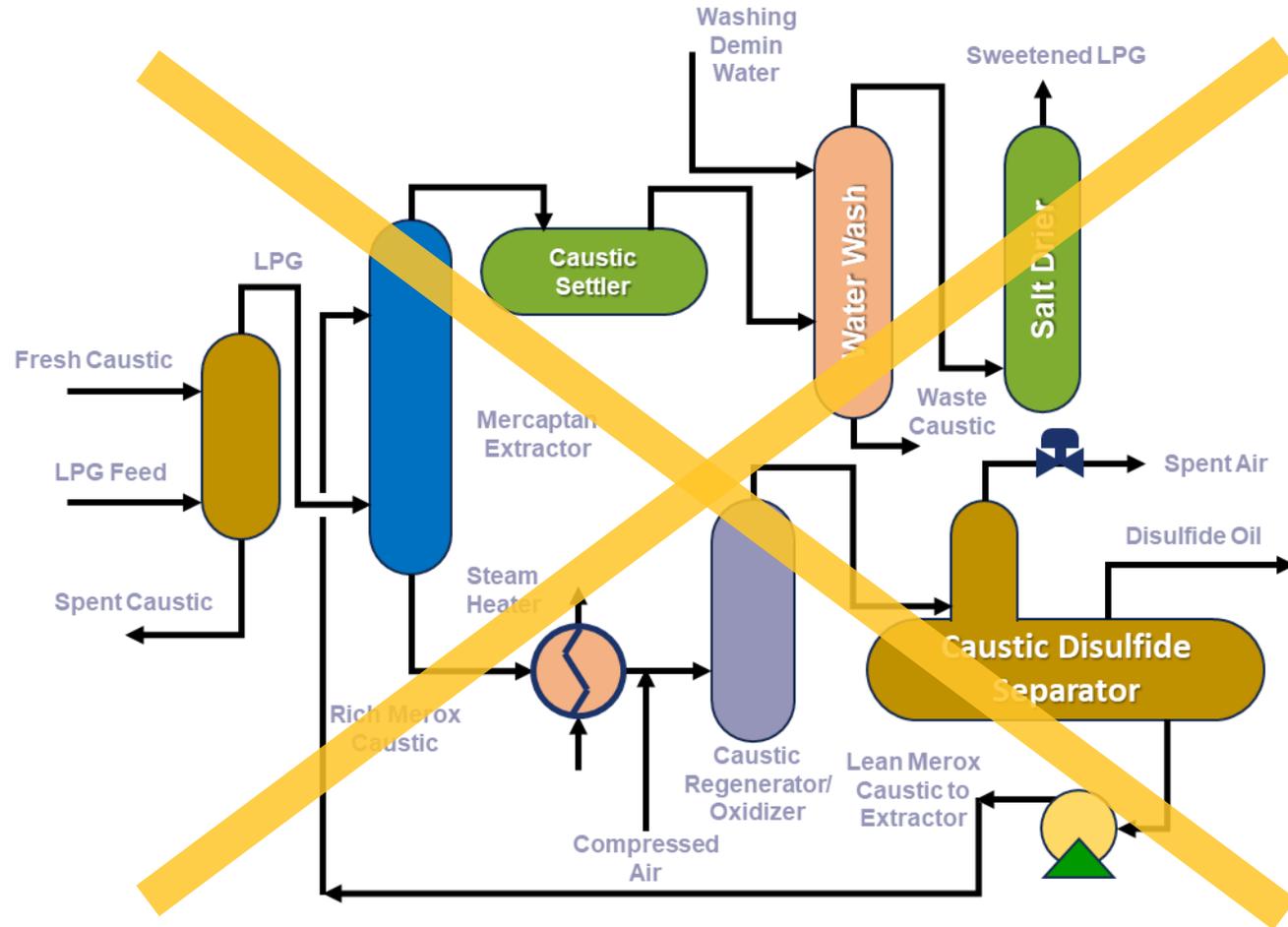
Packing of spherical powders: sinter over time – Lose surface area and activity

Nanowire Structure

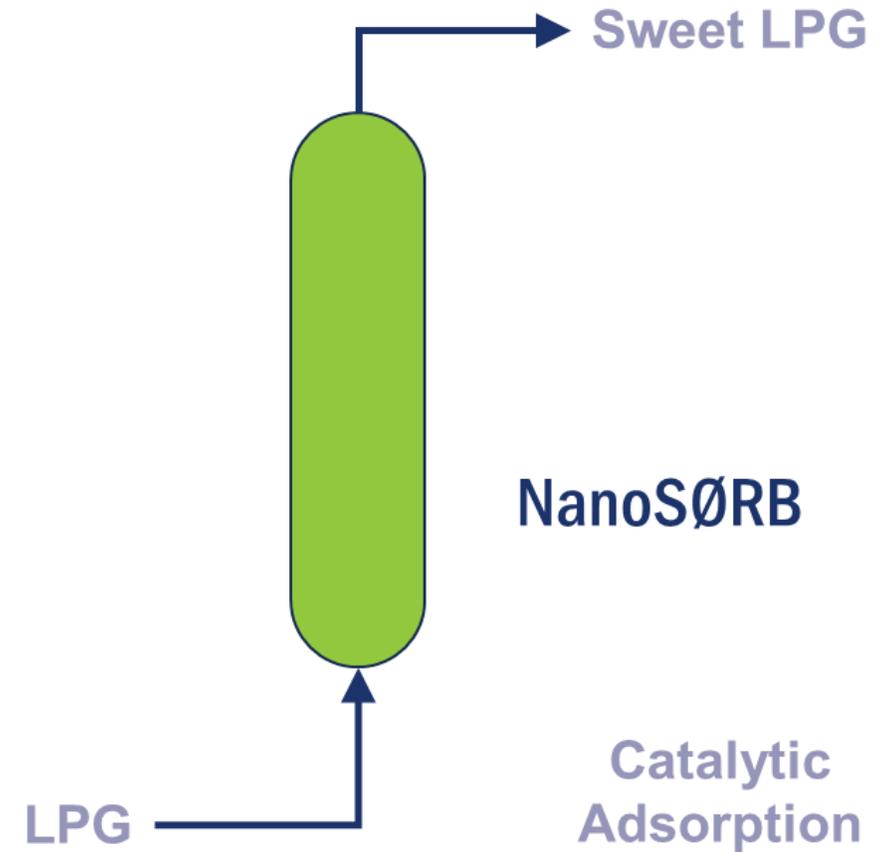


Packing of nanowires: No sintering and loss of area, resulting in higher lifetime

LPG - Caustic Treater Option



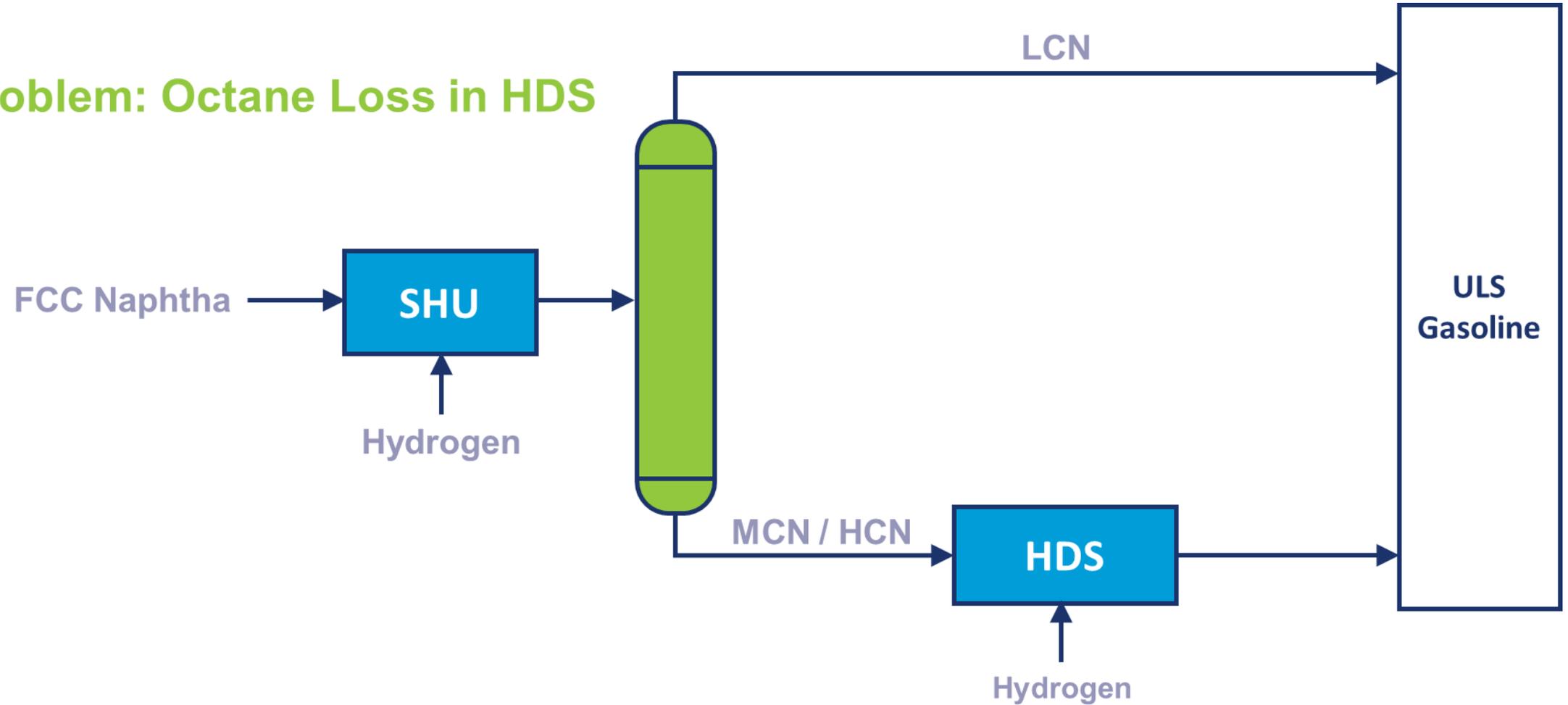
- Fresh Caustic Required
- Continuous Waste



- Regenerable Media
- Eliminates Waste Caustic

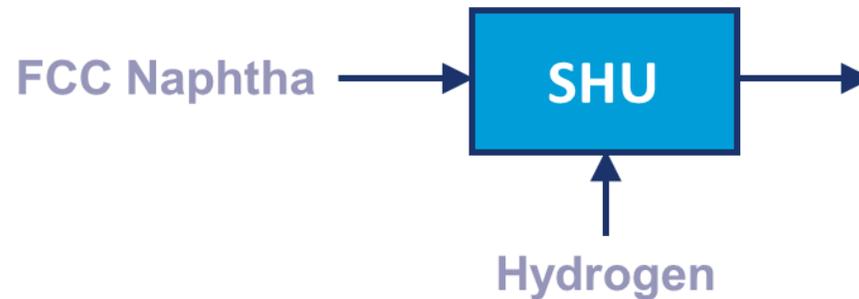
FCC Gasoline - Typical Hydrotreating/Desulfurization Process

Problem: Octane Loss in HDS

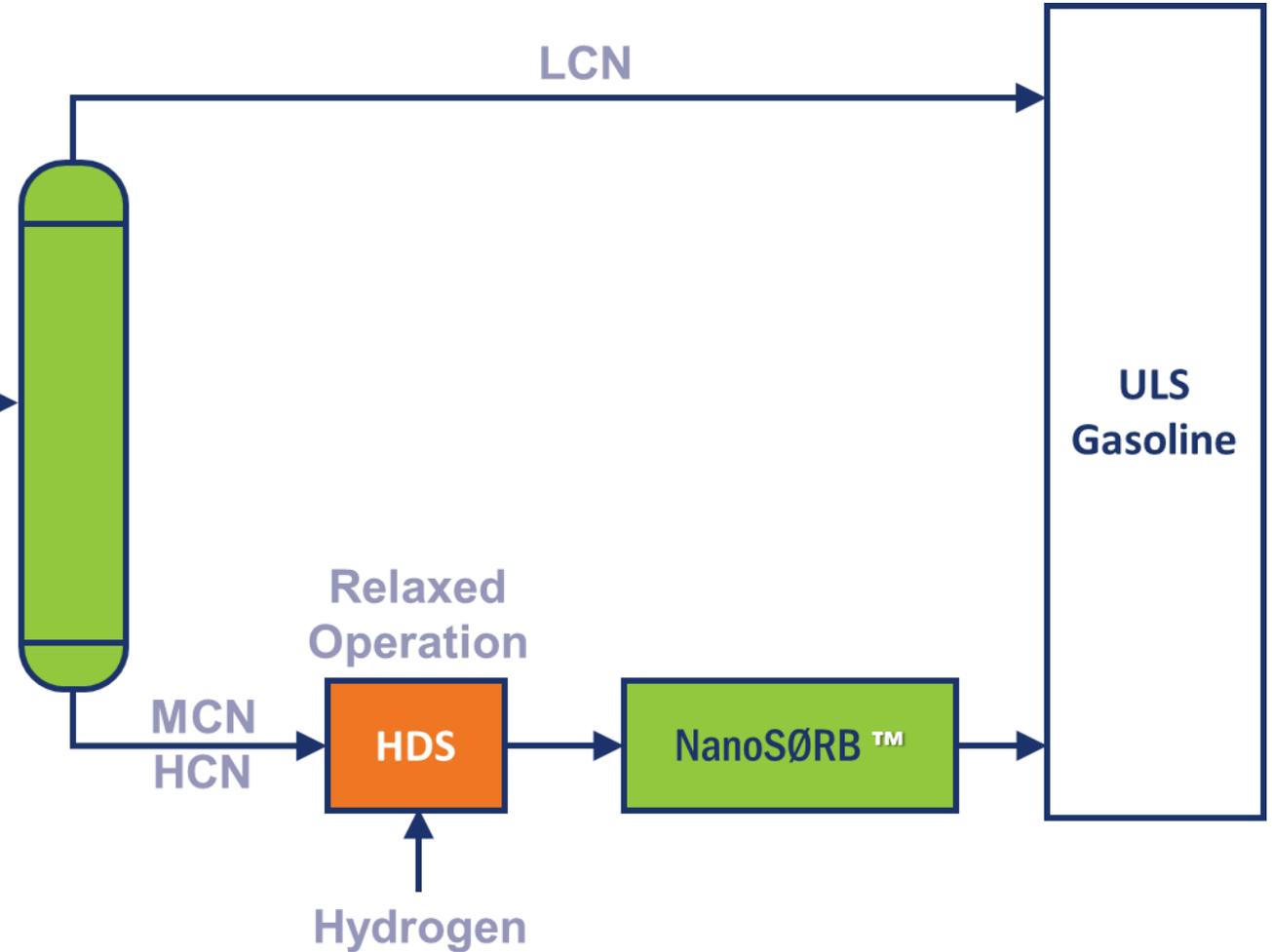


Polishing by Chemisorption

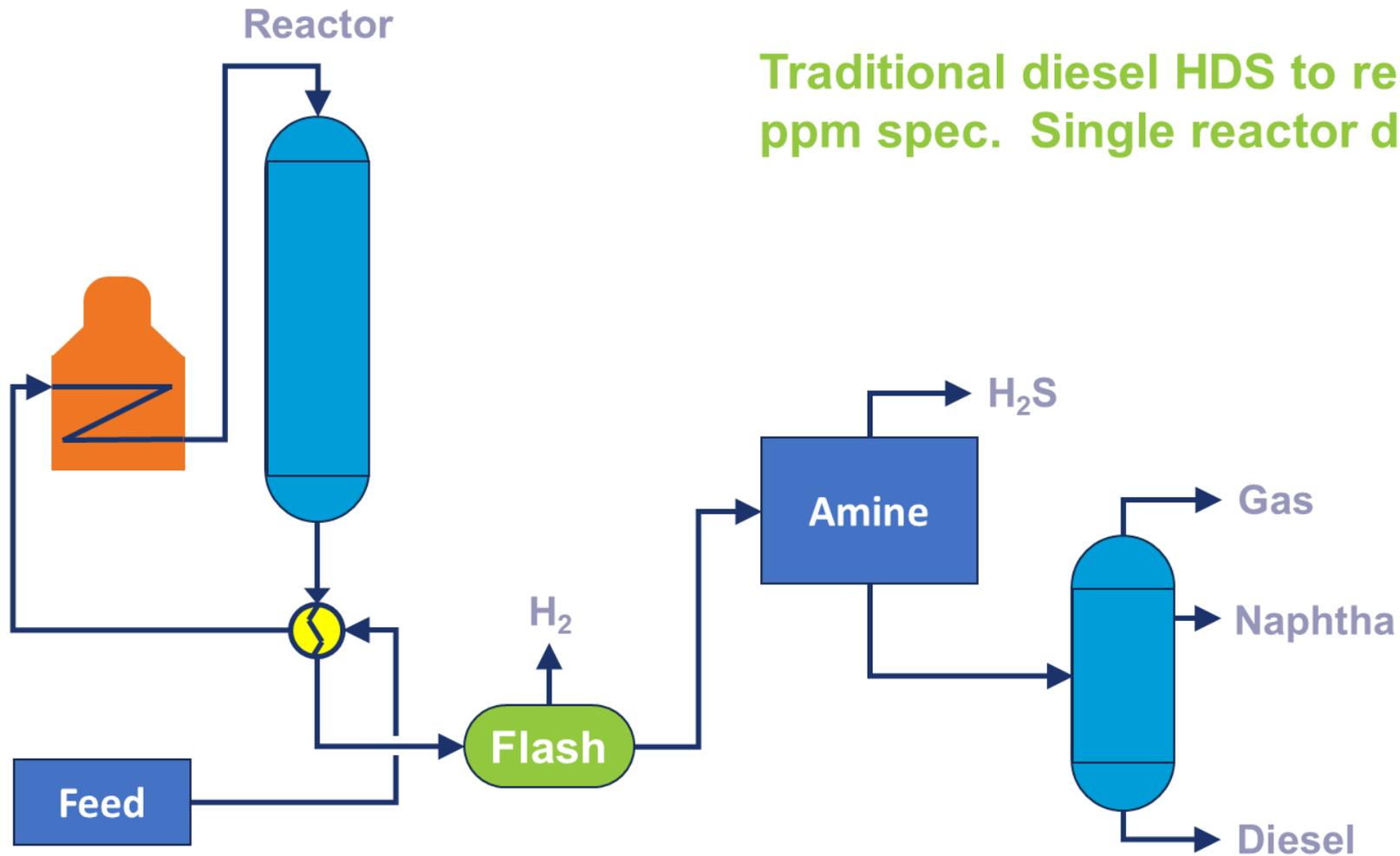
- RON value is retained by relaxing severity in the HDS
- Chemisorption removes the final sulfur traces, with near-zero octane loss



- Fully regenerable media

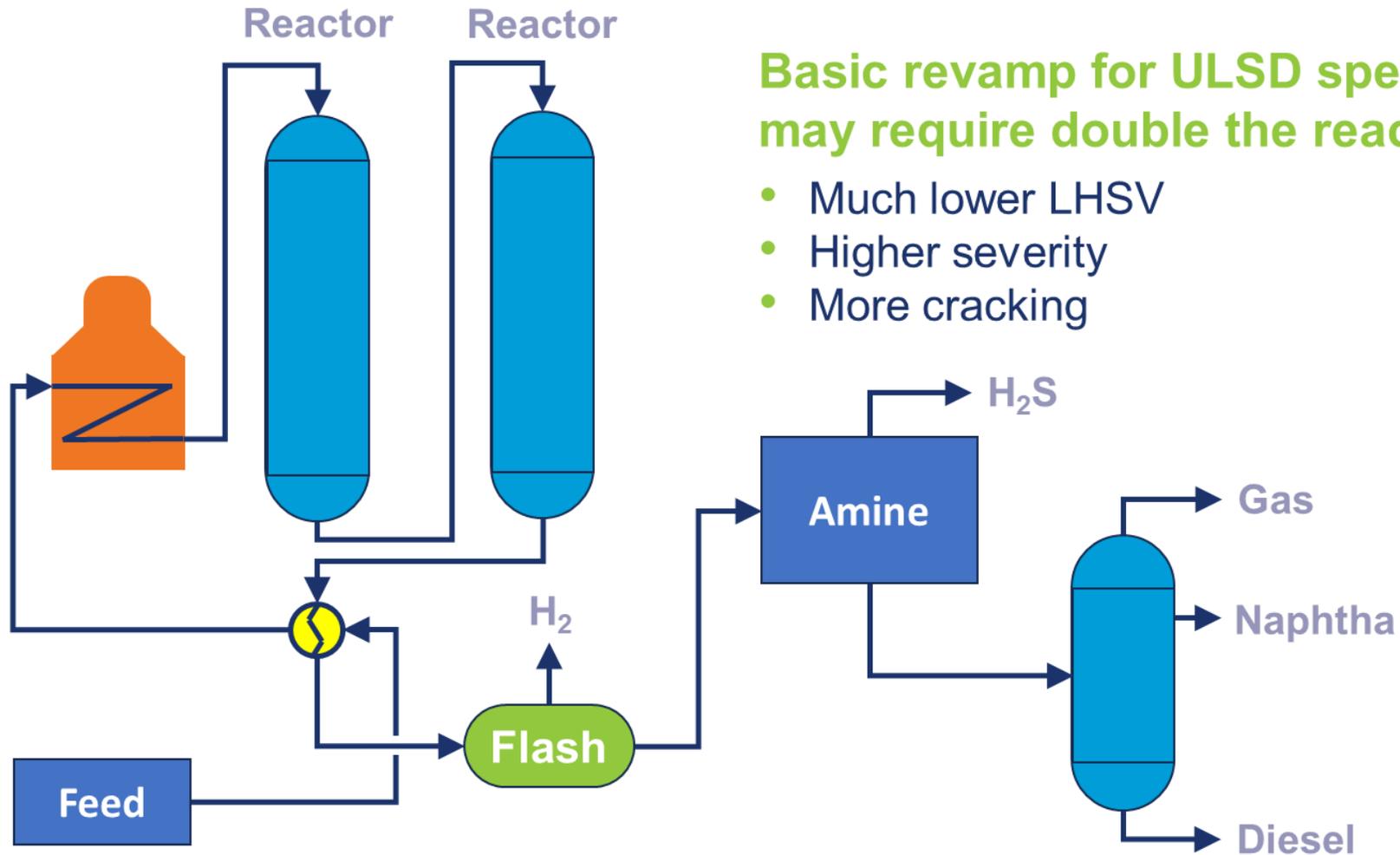


Diesel Desulfurization



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

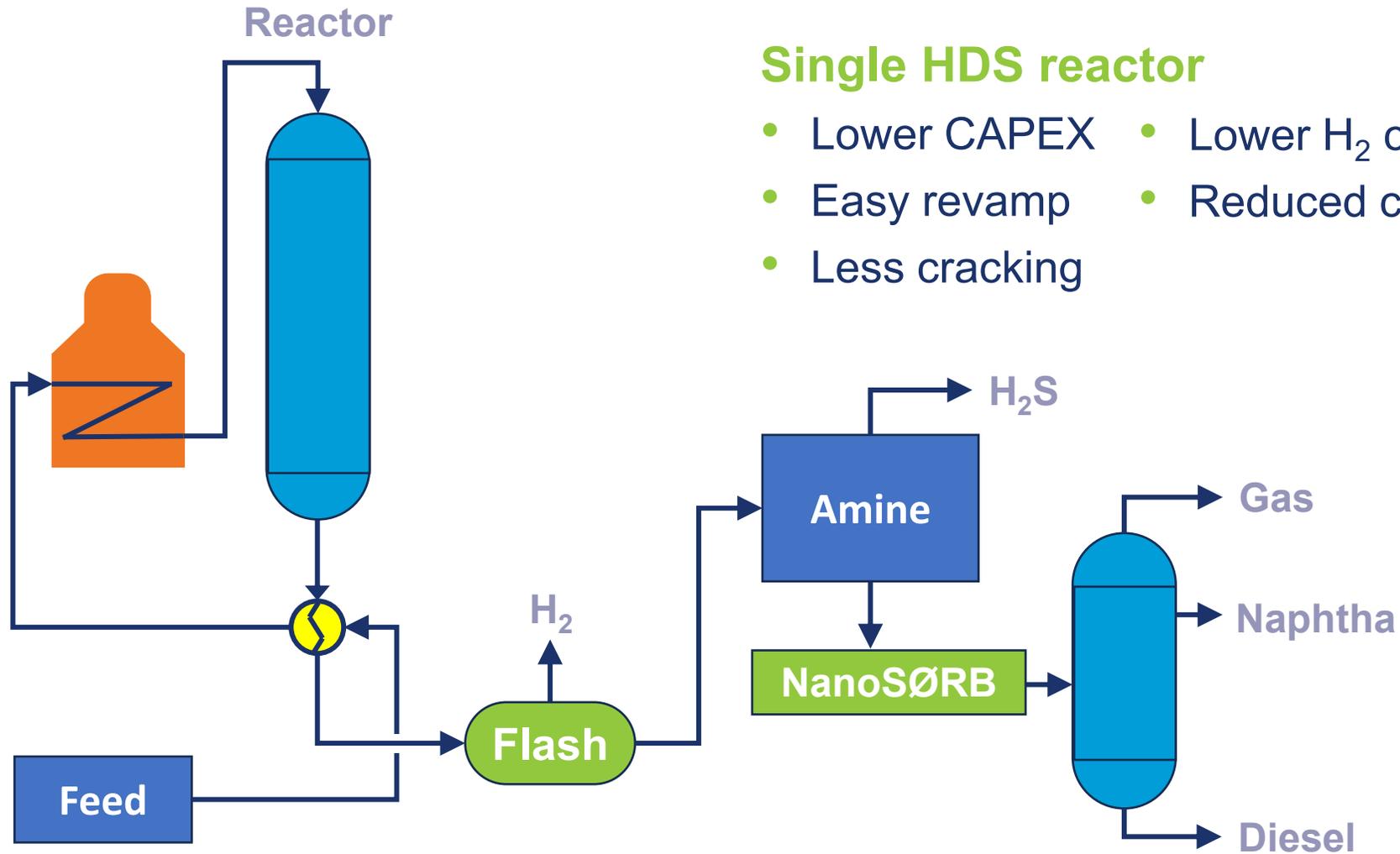
ULSD with New, Full-size Reactor



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
- Lower H₂ consumption
- Easy revamp
- Reduced catalyst quantity
- Less cracking

NanoSORB™ Successful demonstration for ULSD: Texas refiner

- Diesel feed flowrate: 1.5 gpm (51 BPD)
- LHSV = 2 hr⁻¹.
- Pressure at product separator: 200 psig
- Average temperature of reactor: 650 °F
- H₂/HC ratio: 300SCF/bbl (54Nm³/m³)

Refiner is kickstarting engineering for 4000 bpd unit



Successful demonstration for ULSD: Texas refiner

Data Point	Reactor T (°F)	Reactor P (psiG)	Diesel Feed Rate (GPM)	LHSV (hr ⁻¹)	Hydrogen (SCFM)	Sulfur In (ppmw)	Sulfur Out (ppmw)
#1	651	200	1.18	2.5	8.5	270-300	12
#2	660	200	1.18	2.5	8.5	270-300	11
#3	659	200	1.18	2.5	8.5	270-300	<5
#4	659	200	1.18	2.5	8.5	270-300	<5
#5	660	200	1.18	2.5	8.5	270-300	7
#6	659	200	1.18	2.5	8.5	270-300	<5
#7	660	200	1.18	2.5	8.5	270-300	<5
#8	661	200	1.18	2.5	8.5	270-300	4
#9	660	200	1.18	2.5	8.5	270-300	<5
#10	660	200	1.18	2.5	8.5	270-300	5
#11	660	200	1.18	2.5	8.5	270-300	13
#12	661	200	1.18	2.5	8.5	270-300	10
#13	659	200	1.2	2.5	8.5	270-300	8

Detection limit of TOTAL S analyzer is 5 ppmw

Summary

- Development of new media and catalysts opens doors for:
 - SO₂ 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™.



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