Options for improving hydrogen network operations

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Efficiently operating a refinery hydrogen network is a challenge due to the breadth and complexity of the network. While efficient use of H_2 represents significant operating cost savings, it is a mistake to manage the network on the basis of H2 losses alone. The effect of H_2 on process performance and margin must be managed at the same time. Major improvements can be achieved through H_2 recovery projects, but we have also found many other opportunities to improve H_2 network operations.

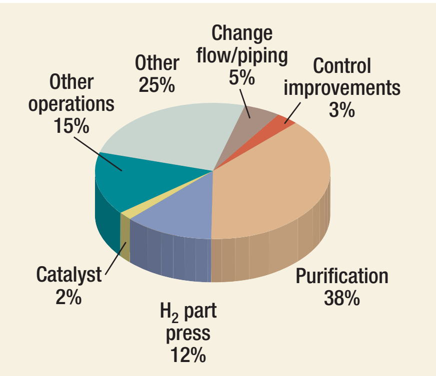

FIG. 1. A breakdown of benefits from 7 recent studies ($137MM/yr total).

Fig. 1 and Fig. 2 represent benefits identified during recent UOP H_2 management studies. They reflect the broad potential for H_2 network improvement. The capital projects all have simple payback of less than two years. It's important to note that the benefits for advanced controls are understated here because these analyses are based on optimizing a snapshot of steady-state operation and don't consider dynamic issues.

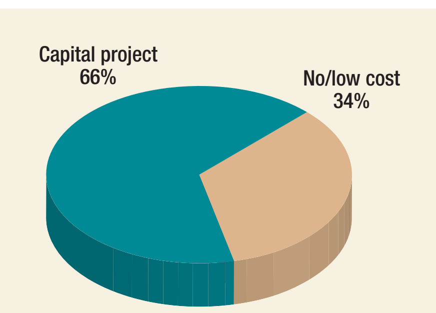

FIG. 2. Additional breakdown of benefits from 7 recent studies ($137MM/yr total).

Managing H2 purity. Continuously operating at target H_2 partial pressure is a key goal. Operating a hydroprocessing unit at lower H_2 partial pressure than target puts the catalyst at risk and negatively impacts process performance. Operating at higher than target purity leads to excess H_2 wasted to fuel. There is usually some "handle" to turn such as a bypass around PSA, mixing different purity makeup streams or adjusting purge rate, but, in reality, the low frequency of analyses and operator attention elsewhere leads to significant variation in this target variable. A further degree of optimization is available when the refiner considers changing the target with varying feed properties and charge rates.

Network topology. The mixing and matching of H_2 sources and sinks provides opportunities to increase H_2 efficiency through modification of the network topology including adding cascades, minimizing purges, mixing makeup streams of different purities.

Balancing H2 production and consumption. Many refiners produce more H_2 in the H_2 plant than is required and burn the excess as fuel, as a means to maintain a safety margin for the ability to provide more H_2 quickly to consumers when there is a change in operating conditions. Some refiners send this H_2 to flare. These practices are clearly inefficient and costly. The other extreme is to just let H_2 system pressure swing with upsets. A 100 psig swing in a hydrocracker will swing the H_2 partial pressure in the reactor, which is also inefficient and costly. Improved operating procedures and advanced controls like anticipating demand changes and automatically adjusting H_2 plant rates can greatly mitigate these dynamic issues. UOP and Honeywell Process Solutions see a growing interest in applying process-based advanced process controls (APC) to the refinery-wide network. This is a change from the usual approach of optimizing single process units independently.

Catalytic reformer improvements. Modifications to the existing catalytic reformer to increase H_2 yield can be considered. These opportunities range from small pressure drop improvements to catalyst replacement to revamp to operation at significantly lower pressure.

Hydrogen-to-hydrogen plant feed. Sending H_2-containing streams to H_2 plant feed rather than fuel gas can significantly reduce the feed + fuel required in the plant.

Recovering H_2. H_2 recovery opportunities include adding new purification units, modifying existing purification units so that they perform as new, revamping existing purification units for higher capacity or recovery.

There are other miscellaneous improvements that UOP has found including modifying relief valves so that reactors can be operated at higher partial pressure, compressor debottlenecking and repairing significant leaks in H_2 compressors.

The following case study demonstrates a method of H_2 recovery that combines the addition of new purification PSA and membrane units with debottlenecking of the PSA units for increased capacity.

Case study—Staged exploitation of H2 recovery opportunities. An atmospheric resid desulfurization (ARDS) facility is installed in North America with H_2 make-up for this plant coming from a steam reformer H_2 plant with a product flow of 55 MMSCFD. The H_2 plant employs a large 10-bed PSA unit that removes essentially all the impurities, including nitrogen, from the steam reformer effluent.

As designed, the feed gas to the steam reformer was predominately natural gas, and supplemental feed was derived from the high-pressure vent and the low-pressure flash of the ARDS unit. The high-pressure vent was scrubbed of H_2S and throttled down to steam reformer feed pressure, and the low-pressure vent was compressed to match the steam reformer feed pressure. Fig. 3 shows the overall flow scheme.

To meet the increasing H_2 needs of the refinery throughout the years various revamps have taken place as summarized in the Table 1.

TABLE 1. The history of hydrogen requirement (in MMSCFD) at case study refinery.

Phase	Steam reformer	Membrane	CCR	Total
1 (Design)	55	-	-	55
2	65	5	-	70
3	65	5	50	120
4	85	5	50	140
5	85	5	60	150
6	85	5	75	165

Phase 2—First revamp of steam reformer PSA. The first plant expansion was undertaken in which the target H_2 capacity was increased from 55 to 70 MMSCFD. The first capacity increase was achieved through the debottlenecking of the steam reformer and SMR PSA unit to increase the H_2 output from 55 to 65 MMSCFD. The SMR PSA debottlenecking was achieved through a process redesign and changes to the control system software with essentially no hardware modifications. This was achieved by operating a different process cycle. The unit was able to process more feed gas while still maintaining the design product specification. This increase in feed capacity more than compensated for the decrease in H_2 recovery and the net result was an increase in H_2 production of 18%.

The high-pressure vent stream at over 2,000 psig was routed to a membrane system. The H_2 product was delivered to the suction of the H_2 make-up compressor. This change added an additional 5 MMSCFD of H_2 to the refinery H_2 header.

Phase 3—A new PSA unit. Later, a continuous catalytic reforming (CCR) unit was installed and the net gas was fed to a new ten-bed PSA unit. By compressing the tail gas, it was possible to maximize the H_2 recovery in the PSA while still sending the tail gas to the refinery fuel system. This new CCR PSA unit added an additional 50 MMSCFD of H_2 to the H_2 balance. Eventually, this unit was revamped, as discussed (in Phase 5) below.

Phase 4—Second revamp of steam reformer PSA. A second revamp took place to further increase the capacity of the steam reformer and its PSA from its operation at 65 to 85 MMSCFD. This additional debottlenecking required modifications to many of the control valves and piping on the piping skid, but maintained the existing adsorber vessels and mixing tanks. The flow rates had increased by over 50% since the original design. A close working relationship between the refiner, UOP and valve vendor allowed the revamp design and hardware to be completed and ready for installation less than six months after the project was authorized. All field modifications were completed during a two-week turnaround.

Phase 5—Revamp of CCR PSA. The CCR PSA unit was later debottlenecked, as additional feed was available from the catalytic reformer. By installing additional tail gas compression and updating the PSA cycle, the unit's H_2 production was increased to 60 MMSCFD while maintaining the design product specification.

Further increases are possible to make cycle changes similar to the types implemented in the steam reformer PSA unit. The predicted H_2 production is increased to 75 MMSCFD. This revamp will reuse the existing adsorber vessels and adsorbents but would require changes to the existing valves and piping skid. These changes will allow the CCR PSA to produce 50% more H_2 than the original design and will maintain the H_2 recovery already obtained from the previous revamp. This revamp design will fully utilize all the tail gas compressors to their full capacities. The revamped flow scheme following Phase 5 showing current operation is shown in Fig. 4. ■

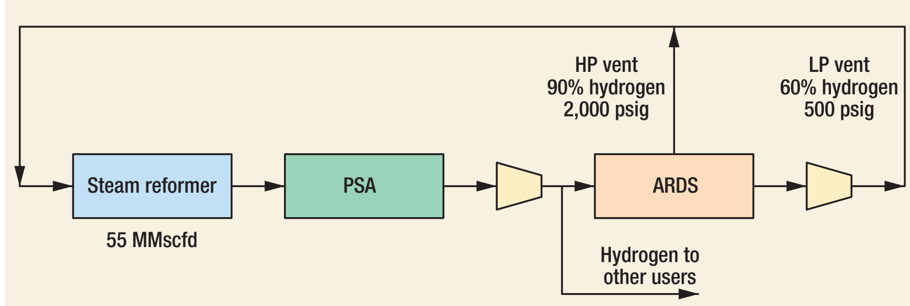

FIG. 3. Original flow scheme of the case study.

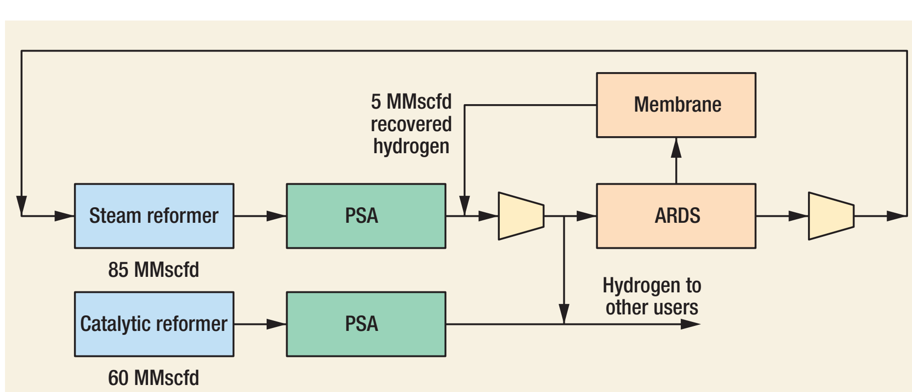

FIG. 4. The revamped flow scheme after Phase 5, otherwise known as current operation.