The first industrial hydrogen pressure swing adsorption (PSA) system started up in 1966 at a petrochemical facility in Texas. The system was designed by the Union Carbide Corporation (UCC) and was later added to Honeywell UOP’s technology portfolio. Since then, more than 1000 Polybed™ PSA systems have been designed by UOP worldwide, with approximately 65% being installed in oil refineries to recover and purify hydrogen from steam methane reformer (SMR) syngas or various hydrogen containing refinery offgas streams.

While Polybed PSA systems have proven to maintain performance over decades, system revamps can be an economic way to take advantage of changing feeds or the need for increased capacity. The case studies below illustrate a series of system revamps that provided good...
economic returns by enabling increased capacity and recovery, while maximising the original PSA investment.

Case studies

Case 1: revamping a refinery in Southeast Asia
In 1994, a refiner in Southeast Asia started up a UOP CCR Platforming™ (catalytic reforming) unit. Two years later, the refiner commissioned a 10-bed UOP Polybed PSA system, supplied as a packaged plant, to recover and purify a fraction of the 120 900 Nm³/hr platforming net gas. After commissioning under UOP supervision, the plant met its performance guarantees of 89 500 Nm³/hr capacity, 99.7% purity and 88% recovery.

Additional value
In 2005, after more than 10 years of successful operation, the unit was due for inspection, per the local regulations for pressure vessels, which required unloading the adsorbent. To avoid the risk of poor performance after startup and likely dust formation, the user decided to reload the vessels with fresh material. The refiner wanted to evaluate if the PSA unit would be able to process a larger fraction of the available platforming net gas.

During the plant turnaround, UOP reloaded the 10-bed PSA System with new, high performance adsorbent which, in combination with a revised PSA cycle, enabled the unit to operate at an improved capacity of 100 000 Nm³/hr feed rate and an increased recovery of 89%. As a result of the revamp, the net additional value to the refiner was US$4.14 million/y (using US$1200/t for purified hydrogen and US$4.5 million/Btu for fuel gas). The payback time of this reload was less than 12 months.

Additional capacity
In 2008, the refiner needed even more hydrogen to operate its hydrotreating units at higher severity. UOP conducted a process study to evaluate the options and determined that there were two good revamp options to achieve higher capacity:
- Reload the current unit with the latest, higher performing adsorbents.
- Expand the existing 10-bed PSA to a 12-bed to meet the capacity increase and maintain recovery at 89%.

It was ultimately determined that the maximum increase in hydrogen production would come from converting the unit to a 12-bed system. In that configuration, the unit would handle the full net gas rate available of 120 900 Nm³/hr and continue to operate at a recovery rate of 89%. In addition to the detailed engineering, the UOP scope of supply for this revamp included two additional vessels with adsorbents, the extension of the valve skid with the control valves needed for the two new vessels, adsorbent loading with startup services, and an upgraded PLC control system for the new configuration. Value was conserved for the refiner by reusing the adsorbent installed in the original 10 adsorber vessels. The benefit to the refiner from this 20% capacity increase is estimated at US$7.59 million/y (using the same values as before for hydrogen). The payback time for this change in PSA configuration was also less than 12 months.

This case study illustrates that UOP can bring significant value to its PSA customers through continuous development, which enables improved future performance. The solutions are flexible, providing

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Table 1. Case one economics summary

<table>
<thead>
<tr>
<th>Year</th>
<th>Configuration</th>
<th>Feed flow rate</th>
<th>H₂, recovery</th>
<th>Delta flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>10-bed</td>
<td>89 500</td>
<td>88</td>
<td>Original design</td>
</tr>
<tr>
<td>2005</td>
<td>10-bed</td>
<td>100 000</td>
<td>89 +10%</td>
<td>Adsorbent reload</td>
</tr>
<tr>
<td>2008</td>
<td>12-bed</td>
<td>120 900</td>
<td>89 +30%</td>
<td>Additional vessels</td>
</tr>
</tbody>
</table>

Figure 1. Typical Polybed PSA valve and piping skid.
companies with economic solutions for a variety of new challenges, and system wide, which reduces cost by maximising the reuse of the existing equipment and materials.

Case 2: expansion at a refinery and petrochemical site in the Middle East
A refinery and petrochemicals site in the Middle East had a 10-bed Polybed PSA system that had operated successfully since 2001. The feed to the PSA was primarily the net gas from the refinery’s catalytic reformer, and a recycled stream from the polypropylene plant was mixed with the net gas to maximise plant-wide available hydrogen. The original PSA unit was designed for a feed capacity of 70 000 Nm³/hr and a hydrogen recovery of 90%. The 99.9% pure hydrogen from the PSA was sent to the refinery’s hydrogen network. The hydrocarbon rich PSA tail gas was sent to the adjacent steam cracker for further cracking.

In 2014, UOP was asked to evaluate the possibility of increasing the feed capacity of the unit by 20% to 85 000 Nm³/hr, along with a change in feed composition. UOP conducted a process study to evaluate the options and determined that there were two good revamp options:

- Reload the existing 10-bed unit with new, higher performing UOP adsorbents and trade one percentage point in recovery to achieve the expected capacity.
- Expand the existing 10-bed PSA by adding two adsorber vessels to meet the capacity increase and maintain recovery at 90%.

The user evaluated the options and concluded that the reload of the 10-bed unit met the requirements from a Capex and Opex standpoint. In this case, increasing tail gas production has unique value since the tail gas contains more than 60% hydrocarbons, which increases net propylene production when recycled back to the steam cracker. With a 20% increase in feed, the net hydrogen production still increases even though recovery drops by nearly 1%. This increase in hydrogen production satisfied the refiner’s hydrogen needs, so a minor reduction in recovery was acceptable.

The UOP scope of supply included high performance adsorbents (due to the change in feedstock composition), the upgrade of the control logic to the new PSA cycle and valve modifications to the PSA skid.

The time to production was another key decision favouring the reload. Reloading with new adsorbents would be implemented within 25 weeks from the date of adsorbent order while the expansion could take twice as long due to the lead times on certain hardware. Enabling the increased polypropylene production in just six months (versus 12 - 15 months for the alternative) contributed to a less than one year payback for this revamp project.

This case study illustrates that no two revamps are the same. In this case, the tail gas stream carried the value of the project because of the increased polypropylene production. It should also be noted that the expansion remains an open option should the refinery ever need additional pure hydrogen.

UOP develops revamp strategies together with the end user – it is important that an open dialogue is maintained during the project development phase so that the customer’s problem, expectations and economics are fully understood. Furthermore, UOP maintains a team of dedicated engineers to support companies during the lifetime of the unit, and develops solutions to help maximise return on investment.

Conclusion
In today’s economic environment, with constrained capital expenditure, revamping Polybed PSA systems is a relatively low cost investment that can allow facilities to meet their increased production targets with a short payback period. Continued development of Polybed PSA technology allows units to be revamped or retrofitted during the unit’s mechanical lifetime, adjusting to changing operating conditions and industry demands and contributing to the overall profitability of the user’s operation.