Capturing Opportunities for *Para*-xylene Production

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The *para*-xylene market is currently experiencing an up-cycle for producers. In recent years, new capacity coming on-stream has not kept pace with steadily increasing demand. Existing producers can capitalize in this environment by maximizing production. Since most plants are already operating at full capacity, further increases may require some type of modification. Developments in process technology are the key to enabling revamps that allow low cost expansions that can be executed quickly.

UOP has developed and successfully commercialized its latest breakthrough in *para*-xylene technology. Use of ADS-37™ adsorbent, UOP's latest adsorbent for the Parex™ Process, while carrying out a high capacity revamp, can result in a capacity increase in the range of 10 to 30% compared with operation with previous generation Parex adsorbents. An increase of this magnitude exceeds the benefit historically afforded from new adsorbents. The improvements associated with ADS-37 adsorbent and high capacity revamp can be implemented quickly and at relatively low cost, with payback of as little as seven to eight months.

In 2006, the Aromatics (Thailand) Public Company, Ltd. (ATC), a *para*-xylene producer with a facility located in Map Ta Phut, Thailand, was able to capitalize on just such an expansion. The entire project took less than eight months from initial discussions with UOP through successful commissioning of the high capacity revamp. ATC's *para*-xylene production

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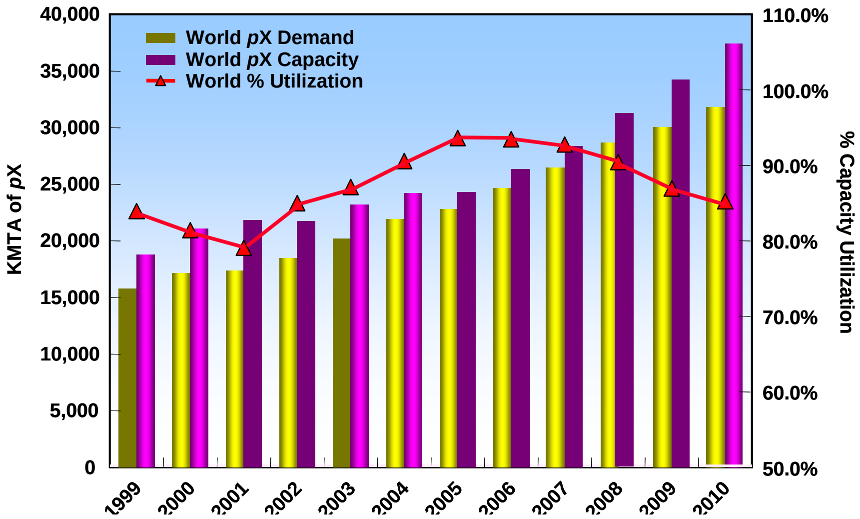
capacity, which had previously been pushed to the limit of its ADS-27 adsorbent, was increased by 12% when an ADS-37 adsorbent reload and high capacity revamp were implemented.

Economic Environment for *Para*-xylene Producers

Para-xylene is used in the production of polyethylene terephthalate (PET), which is used as polyester fiber, film, and resin for a variety of applications. Because of downstream demand, the *para*-xylene market is robust and generally sees steady year-on-year demand growth in the range of 6-8% per year. Despite this, *para*-xylene capacity expansions tend to follow a more cyclic pattern, with booms and busts, resulting in swings in operating margins for producers.

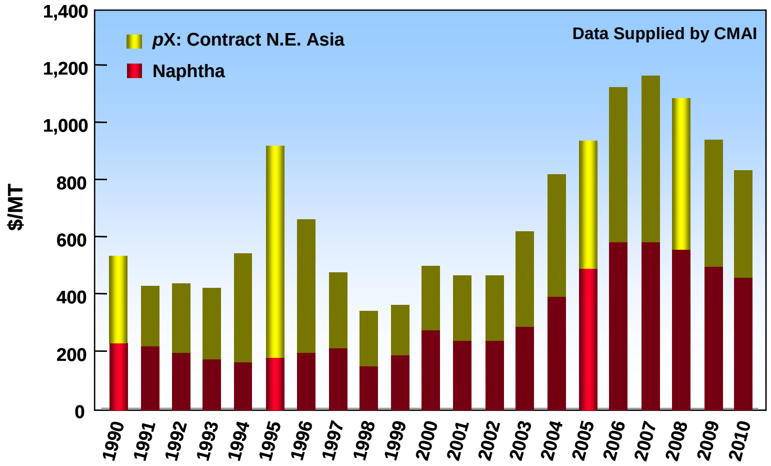
Favorable conditions in the mid-1990s encouraged producers to expand capacity and led to an overbuilt market by the late 1990s. By 2001, worldwide *para*-xylene production capacity exceeded the demand by more than 4.5 million metric tons per annum (MMTA), lowering the average capacity utilization to less than 80%. Figure 1 shows the world supply/demand balance for *para*-xylene and capacity utilization from 1999 through the 2010 forecast.

Figure 1 – World *Para*-xylene Supply/Demand Balance



In the 2001 timeframe the market was sluggish. The spread of the price of *para*-xylene over naphtha, which had risen dramatically and reached a peak of $741 per metric ton in 1995, had fallen to $176 per metric ton by 1999. Figure 2 shows the world average naphtha and *para*-xylene pricing from 1990 through the 2010 forecast, to give a historical perspective on periods of high and low profitability for producers.

Figure 2 – *Para*-xylene Price History and Forecast



The situation of low margins remained for several years through 2002 where producers had difficulty to cover their operating costs, let alone to make profits seen during the mid-1990s. With an expectation of low operating margins due to the large surplus of production capacity, potential producers were reluctant to commit to new *para*-xylene projects in the early 2000s.

Throughout this period, growth in the downstream market for PET remained strong. From the mid-1990s through 2006, world demand for *para*-xylene steadily increased at a rate of nearly 8% per year, and recently the *para*-xylene market has tightened considerably. With little new capacity coming on stream in the 2001-2004 timeframe, demand growth consumed virtually all the surplus *para*-xylene production capacity from the late 1990s build-up. By 2005, the surplus had fallen to less than 1.5 MMTA, and worldwide capacity utilization had increased to 94%. The revival of new large scale project commitments that began in earnest in 2004 has to date only had a minor impact on providing much needed new capacity, as many of these new projects are not expected to come on stream until the 2007-2010 timeframe. By the end of 2006, new production capacity only began to meet the pace of rising demand growth, and worldwide capacity utilization is expected to remain above 90% into 2009.

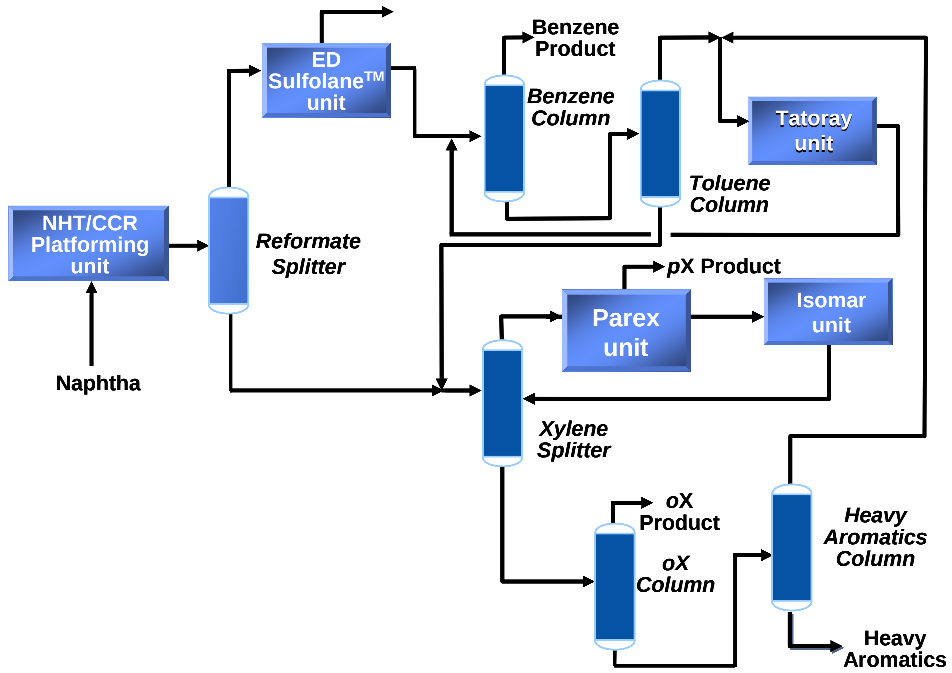
It is worthwhile to note the potential instability that the market experiences when all plants collectively operate at such high rates. In this environment, any brief outage by a major producer can result in a sudden temporary spike in the *para*-xylene price. This was seen in July 2006, when the spot market price in Taiwan was reported by the global chemical market intelligence service ICIS as having reached $1,610 per ton, an increase of 25% over the previous month.

The average annual price spread of *para*-xylene over naphtha steadily rose to $540 per metric ton in 2006 and is expected to remain in the range of $400-500 per metric ton for the period 2007-2010, allowing an extended period for producers to achieve high margins not experienced since the mid-1990s. For the remainder of the current up-cycle, which is expected to last into 2010, increasing capacity may be the most effective way to improve the competitiveness of an existing facility. Developments in process technology are the key to enabling revamps that allow low cost expansions that can be executed quickly. The ability to get additional capacity on-stream in the shortest time possible is the key to capitalizing on favorable market conditions before competitors.

UOP Aromatics Complex to Produce *Para*-xylene

A typical processing flowscheme to produce high purity *para*-xylene and benzene from a naphtha feedstock, with *ortho*-xylene as a co-product, is shown in Figure 3. This scheme shows a number of processing steps where the naphtha is first hydrotreated and then fed to the CCR Platforming™ Process unit to produce an aromatic stream rich in benzene, toluene, and C_8 and heavier aromatic compounds. *Para*-xylene is generally the most valuable C_8 aromatic isomer, so the additional processing steps involve separating and converting the other compounds at as high a yield as possible to *para*-xylene and benzene. Toluene and C_9 and heavier aromatic compounds are converted to benzene and C_8 aromatics in the Tatoray™ Process unit. High purity *para*-xylene is recovered at high recovery from a C_8 aromatic-rich stream in the Parex Process unit. The *para*-xylene depleted C_8 aromatic stream is brought back to equilibrium in *para*-xylene concentration in the Isomar™ Process unit, thereby maximizing the yield of *para*-xylene from available feedstock.

Figure 3 – UOP Aromatics Complex



The Parex Process, the key to the production of high purity *para*-xylene, uses a selective and proprietary solid adsorbent developed by UOP to separate *para*-xylene from a mixed C_8 aromatic stream. Commercial Parex Process units typically are able to produce 99.9 wt% *para*-xylene purity at greater than 97% recovery.

Historical Methods to Increase Capacity

During times of high profitability, aromatics complexes are often pushed to the limit of the Parex Process unit. Producing incrementally more *para*-xylene can require modification to the aromatics complex. Historically, there have three methods to increase *para*-xylene production when the Parex Process unit is operating at full capacity:

1. Undertaking a major revamp of the aromatics complex by modifying and/or adding equipment.
2. Addition of new technology and re-configuration of the aromatics complex.
3. Replacement of the existing adsorbent in the Parex Process unit with a more modern, higher performing adsorbent.

Each of the above methods has its advantages. Carrying out a major revamp of the aromatics complex typically offers the potential to allow a greater increase in operating capacity than adsorbent replacement alone. For producers looking to increase capacity by more than 20%, revamp of the existing complex can often be done in a cost effective way by modifying or adding equipment and even by adding a parallel production train. By leveraging the existing capacity on the ground, expansion by revamping offers economic incentives that, on a per ton of incremental capacity basis, are often superior to those of grass roots projects for new capacity using the most modern technologies.

Disadvantages of the major revamp approach are the longer time to implement and the cost relative to adsorbent replacement. Major revamps are large projects that can involve multiple process units and potentially off-site facilities. Typical implementation schedules may exceed one year. While these projects are generally justified based on their long term benefits and on long term production needs, it is not easy to time the implementation of a major revamp to capture a peak period of high profitability.

Technology developments also allow *para*-xylene producers the chance to add new process units and reconfigure the aromatics complex to increase capacity. An example of this involves enrichment of the *para*-xylene concentration of Parex unit feed. The Parex Process benefits from higher *para*-xylene concentration in the feed. Selective disproportionation of toluene to *para*-xylene and benzene via the PX-Plus™ Process can be used to produce a Parex unit feed stream enriched in *para*-xylene, compared with conventional mixed xylenes produced by conventional transalkylation of toluene and C_9 and heavier aromatics. An existing aromatics complex can be re-configured to include a PX-Plus unit by revamping an existing Tatoray unit and by the addition of a new unit, such as a TAC9™ Process unit, to transalkylate heavy aromatics. Such a re-configuration can result in substantial capacity increase. However, the approach of adding technology to expand capacity is similar to the major revamp approach, where the overall project schedule is relatively long and the cost to implement is relatively high.

The third option, replacing the Parex adsorbent with a modern, higher performing adsorbent, can generally be done in the quickest time, allowing a producer to achieve additional production capacity in substantially less than a year from when the decision is made to reload. In a period of high profitability for producers, adsorbent replacement offers the possibility to capitalize on favorable market conditions with only a short shutdown to carry out the reload. In addition to increased capacity, higher performing adsorbent also offers the benefit of lower utility cost per unit of production. This provides an advantage through the life of the new adsorbent that becomes more significant when the market turns down and higher cost producers find themselves in a disadvantaged position.

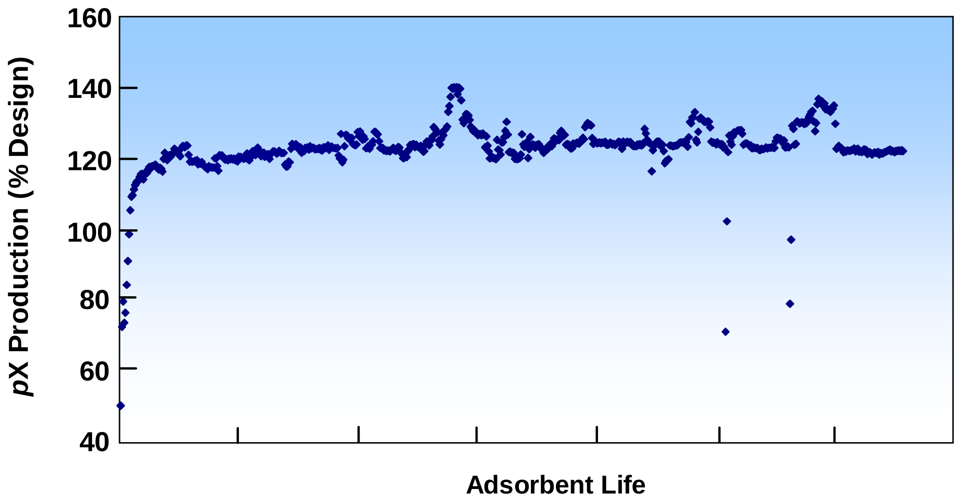
Incremental advances in adsorbent technology have traditionally offered capacity increases that are less than 20% over the previous generation. For example, ADS-27™ adsorbent for the Parex Process, developed and commercialized by UOP in 1990, demonstrated a 15% capacity benefit over its predecessor ADS-7™ adsorbent. Thus, capacity increase by replacing adsorbent can be done quickly, but the magnitude of the increase will be limited by the incremental benefit of the new adsorbent.

<u>ADS-37 Adsorbent and High Capacity Revamp</u>

ADS-37 adsorbent is the latest adsorbent developed by UOP for the Parex Process. It was developed to provide *para*-xylene producers with lower investment and operating costs. It has a unique formulation that gives it a capacity benefit in the range of 6 to more than 20% greater capacity relative to previous generation Parex adsorbents. For existing operators of the Parex Process, ADS-37 adsorbent is a drop-in replacement for its predecessors currently in commercial use, ADS-7 and ADS-27 adsorbents. In new grass roots unit applications, ADS-37 adsorbent offers the benefits of greater *para*-xylene production capacity from a fixed investment.

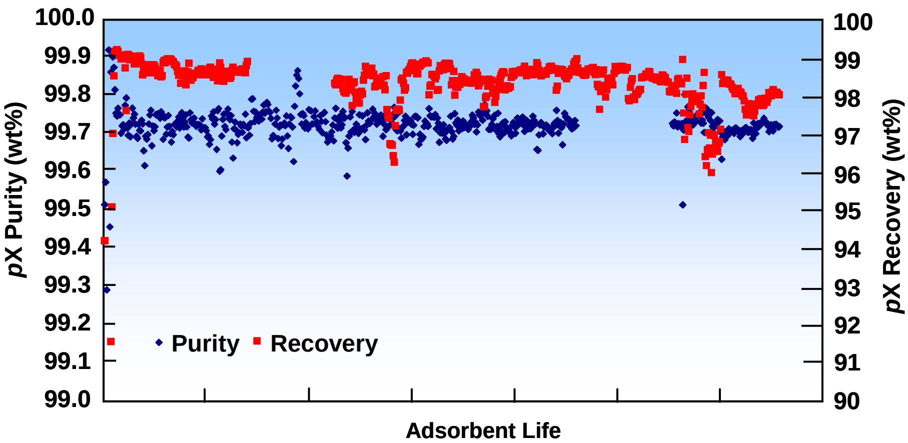
Development of ADS-37 adsorbent was completed in 2003, and it was first commercialized in November 2004 in a Parex unit located in the Republic of Korea. The use of ADS-37 adsorbent, combined with other steps taken to allow increased throughput, has resulted in this plant achieving greater than 120% of its original design capacity, as seen in Figure 4.

Figure 4 – Commercial Parex Unit *Para*-xylene Production with ADS-37 Adsorbent



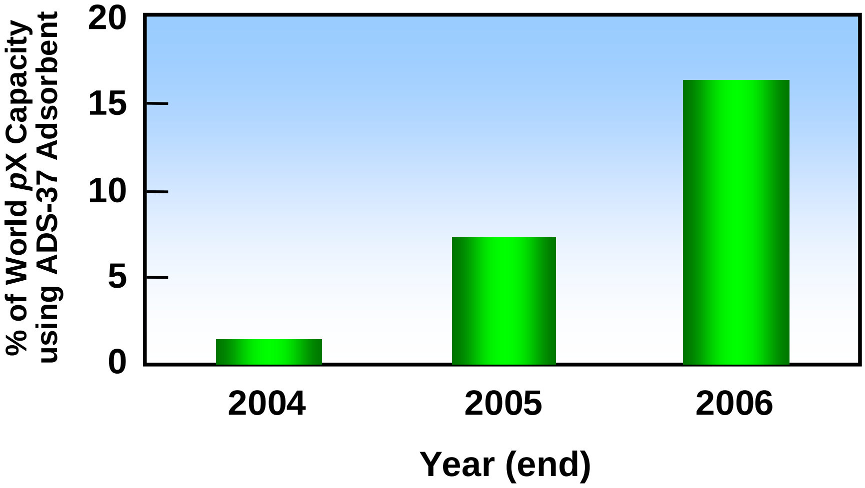
The performance of ADS-37 adsorbent at this facility has also been extremely stable at this high operating capacity, with target product purity of greater than 99.7 wt% at more than 98% recovery over the 2+ years this adsorbent has been in service, as seen in Figure 5.

Figure 5 – Commercial Parex Unit Performance with ADS-37 Adsorbent



Since 2004, the improved performance of ADS-37 adsorbent has been demonstrated in several commercial Parex units. By the end of 2006, a total of 11 commercial Parex units were operating with ADS-37 adsorbent. This substantial and immediate acceptance by the marketplace has resulted in 16% of the world's current *para*-xylene being produced with ADS-37 adsorbent, as is shown in Figure 6.

Figure 6 – World *Para*-xylene Capacity Using ADS-37 Adsorbent



The unique formulation of ADS-37 adsorbent allows it to be operated in an improved mode for even higher capacity increase. UOP has identified conditions required to achieve several percent additional capacity benefit with only a slight modification to the existing Parex Process unit. This modification is known as a high capacity revamp and is enabled by unique features of UOP's proprietary rotary valve technology.

The scope of a high capacity revamp incorporates operation with ADS-37 adsorbent and consists of minor equipment and piping modifications to the Parex Process unit. Since the changes are minor, with no long lead equipment necessary, the high capacity revamp can proceed, from kick-off through basic engineering, EPC, commissioning, and acceptance in less than one year. This allows a high capacity revamp to be planned and carried out within the typical timeframe of an adsorbent reload planning and execution.

For an existing producer with a Parex Process unit using ADS-7 or ADS-27 adsorbent, the economic benefit of replacing the adsorbent and carrying out a high capacity revamp in the current economic environment are summarized in the table below. With favorable economics, both the reload and the high capacity revamp can be independently justified.

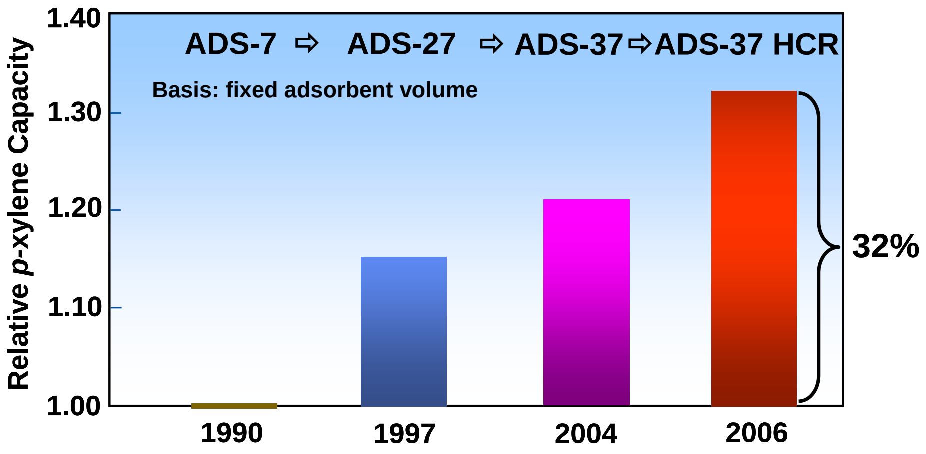
Table – Payback for Parex Adsorbent Replacement with ADS-37 Adsorbent and High Capacity Revamp

Current Adsorbent	*Payout for ADS-37 Reload **	*Payout for Reload and High Capacity Revamp **
ADS-7	10 months	<8 months
ADS-27	2.3 years	14 months

* based on 492 $/MT differential between naphtha and para-xylene

ADS-37 adsorbent with high capacity revamp is the latest innovation in the Parex Process. Figure 7 below illustrates the steady progression of improvements developed by UOP. The cumulative result of these improvements since 1990 is a 32% increase in *para*-xylene production capacity for a fixed adsorbent volume.

Figure 7 – Continued Parex Adsorbent and Process Development



The Aromatics (Thailand) Public Co., Ltd.

The Aromatics (Thailand) Public Co., Ltd., or ATC, was formed in 1989 and is publicly traded, with the Petroleum Authority of Thailand (PTT) being a major shareholder. ATC operates a world-scale *para*-xylene production facility at its site in Map Ta Phut, Thailand. It is an integrated aromatics complex where *para*-xylene, benzene, and *ortho*-xylene are produced from a naphtha feedstock. The source of the naphtha is natural gas condensate produced from the Gulf of Thailand and is supplied to ATC by PTT. ATC's facility is heavily integrated with other upstream and downstream processing facilities within Thailand, which together capitalize on the development of locally available natural resources to the betterment of Thailand and the Thai economy. ATC's local and export markets for *para*-xylene and other products have experienced growth and have been able to absorb additional production from ATC.

ATC has had a strong commitment to preserving the environment since its inception. Feed and product pipeline movement by pipeline and low emission truck loading in a totally closed system ensure emissions are minimized. The company has also undertaken various projects to minimize energy use and to reduce hydrocarbon emissions and has twice achieved a CEL index in the top 10%.

ATC's aromatics complex was originally designed during the 1990s based on UOP technology to produce 312 thousand metric tons per annum (or KMTA) of *para*-xylene, and it was originally brought on stream in early 1997. The complex, in its original configuration, was comprised of UOP Naphtha Hydrotreating, CCR Platforming, Sulfolane, UOP Benzene-Toluene Fractionation, Tatoray, UOP Xylenes Fractionation, Parex, and Isomar Process units. ATC's original configuration is similar to that shown in the typical naphtha-based aromatics complex in Figure 3.

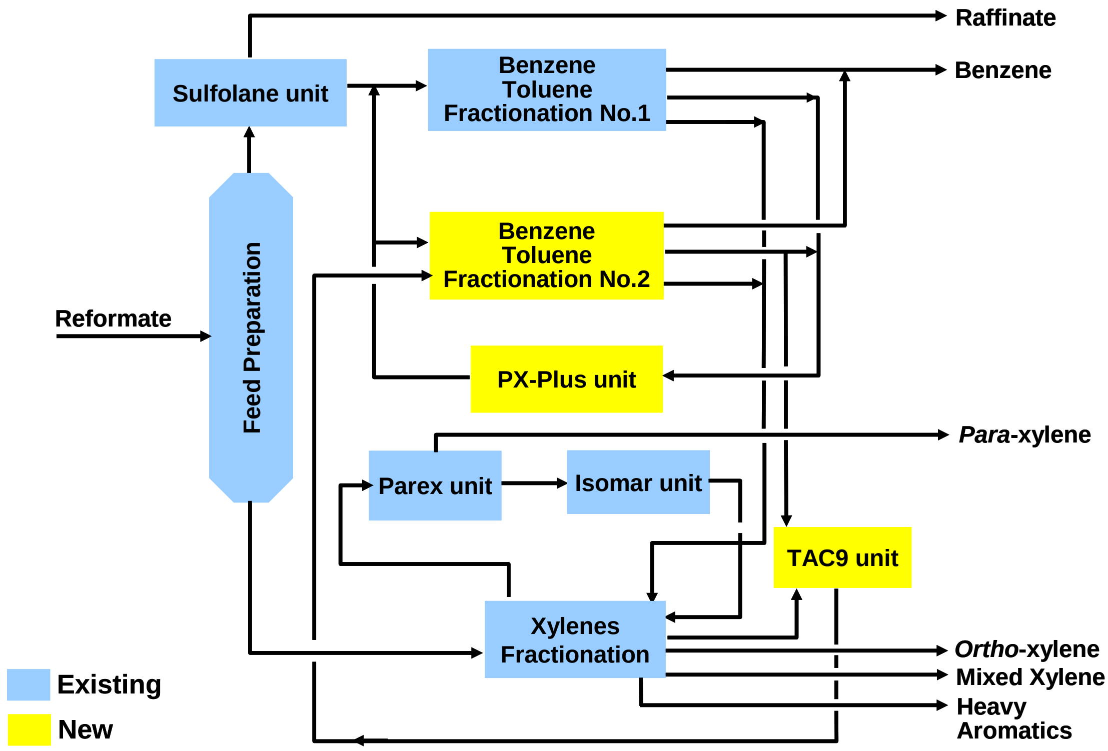
Since its initial start-up, ATC has continuously sought out opportunities to improve its profitability. It has conducted a number of studies with the objectives of increasing production and reducing operating costs. ATC and UOP have worked together through different stages of implementation to achieve ATC's goals.

In 1999-2000, UOP, with ATC's cooperation, carried out a benefits targeting study of ATC's facility. This study uncovered a number of changes ATC could implement, at varying levels of investment, to achieve substantial increase in capacity and reduction in operating cost. Ultimately, the benefits targeting study led to two specific capacity expansion projects ATC could implement, and these were ultimately carried out in two stages.

The first stage was called the Maximum Revamp project, where ATC focused on maximizing capacity from the aromatics complex as it was originally configured. UOP evaluated the performance of the process units and identified limitations of as-supplied equipment to achieve the desired capacity increase. ATC carried out the execution of the revamp with an EPC contractor. This project was completed in 2002, and as a result ATC achieved an increase in capacity of 22% relative to the original design.

The second stage was referred to as the Maximum *Para*-xylene project. For this stage, where an even greater increase in capacity was sought, the configuration of the aromatics complex was modified to allow higher *para*-xylene production by enrichment of the Parex Process unit feed using new UOP technology. The Maximum *Para*-xylene stage was brought into operation in 2004, with a number of modifications made to the plant. These included a revamp of the existing Tatoray Process unit to a PX-Plus Process unit for selective disproportionation of toluene to *para*-xylene and benzene and construction of a new TAC9™ Process unit for the transalkylation of heavy aromatics. The two revamp stages combined led to an increase in the *para*-xylene capacity of ATC's aromatics complex by approximately 59% relative to the original nameplate capacity. The configuration of ATC's aromatics complex following the Maximum Para-xylene project is shown in Figure 8

Figure 8 – Maximum *Para*-xylene Configuration at ATC



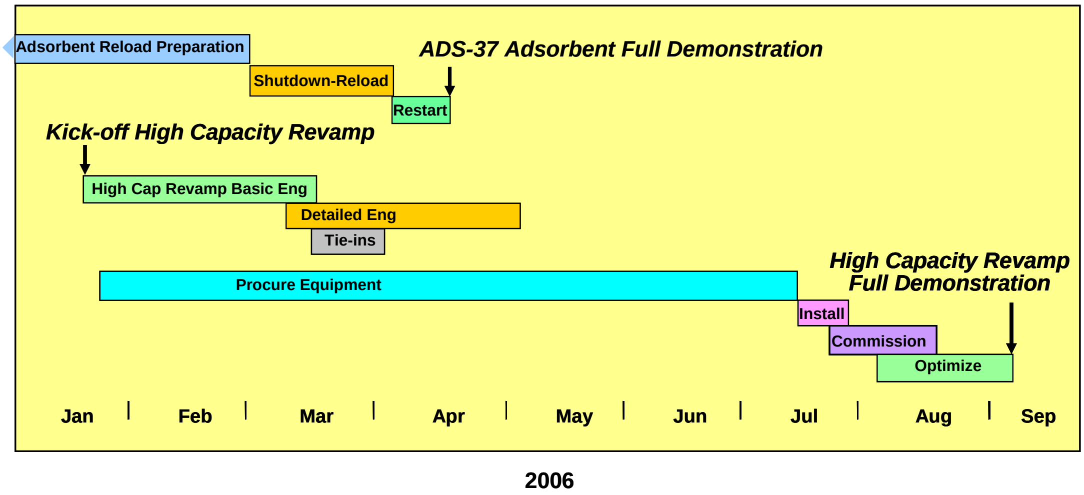
Following the 2004 revamp, ATC's complex was achieving the desired production rate, with the Parex Process unit essentially running at full capacity. The existing CCR Platforming Process unit and UOP Xylenes Fractionation units still had some available capacity, and as a result the aromatics complex was able to export a quantity of mixed xylenes. In late 2004, ATC began making preparation for the replacement of the existing Parex adsorbent with ADS-37 adsorbent. This reload was planned to take place in March 2006, which coincided with ATC's planned turnaround schedule.

Implementation of High Capacity Revamp

In January 2006, UOP approached ATC with the concept of the high capacity revamp as a means of achieving additional capacity from the new ADS-37 adsorbent. Initial discussions indicated that equipment delivery required for the high capacity revamp would be approximately six months. As ATC's adsorbent reload schedule had already been fixed and was less than two months away, it was not possible to delay the reload in order to implement the high capacity revamp during the planned shutdown. At the same time, ATC recognized the opportunity of a further increase in capacity and committed to carrying out the revamp as quickly as possible.

ATC and UOP agreed that UOP would begin basic engineering for the high capacity revamp right away. Prior to ATC's March 2006 shutdown, UOP was able to provide a list of tie-ins for the modifications associated with the high capacity revamp. ATC agreed to install the necessary tie-ins during the shutdown, and ATC and UOP developed a plan to enable bringing the high capacity revamp on-line without the need for a second shutdown. Being able to bring the revamp on-line without a second shutdown was an important part of ATC's decision to proceed. The timeline for the high capacity revamp, shown in parallel to the adsorbent reload, can be seen in Figure 9.

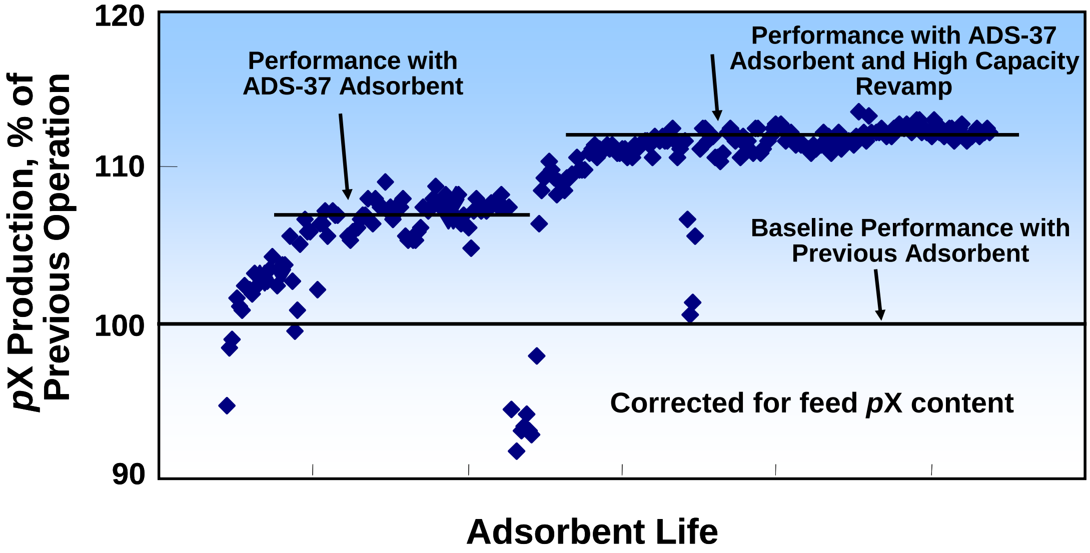
Figure 9 – Timeline for ADS-37 Adsorbent Reload and High Capacity Revamp



The basic engineering was completed, and ATC then had its contractor complete the EPC work. The shutdown to load ADS-37 adsorbent went as planned, and all tie-ins required for the high capacity revamp were made during the shutdown. By early April 2006 the plant was back on-stream, achieving approximately 6% additional capacity because of the ADS-37 adsorbent.

The equipment required for the high capacity revamp was delivered and installed in July 2006, and shortly thereafter commissioning of the new equipment began. Since this was the first commercialization of high capacity revamp, some initial period of optimization was necessary to achieve the maximum benefit. ATC and UOP cooperated in adjusting operation of the unit and collecting the necessary data to allow the benefits of the high capacity revamp to be realized to the fullest extent possible, within the operating constraints of the plant equipment. By early September 2006, ATC had achieved approximately 6% additional capacity above that seen with ADS-37 adsorbent, making the total capacity benefit equal to 11-12% compared with operation with ADS-27 adsorbent. The capacity benefit ATC achieved is illustrated in Figure 10.

Figure 10 – Performance of ADS-37 Adsorbent and High Capacity Revamp at ATC



As an additional note, during the implementation ATC and UOP working together identified that a small amount of incremental additional capacity could be achievable by further adjustment of operating conditions, but this would require additional capital expense and a longer project schedule. Further increase in capacity will be considered by ATC for a future longer-term project. Regardless, ATC achieved a significant benefit that easily justified the High Capacity Revamp.

Implementation of the high capacity revamp at ATC was completed in a timeframe of less than eight months. With the multiple stages of revamp and technology upgrading ATC has carried out since initial start-up, ATC's *para*-xylene production capacity had been raised to 165% of its original design value, all with the original rotary valve system.

Conclusion

Para-xylene producers are currently experiencing an up-cycle that is expected to continue past the end of 2009. New production capacity has not kept pace with the increase in demand, resulting in a situation where more production capacity is needed. Existing producers can benefit greatly from expanding capacity in the near-term, and developments in process technology are the key to enabling revamps that allow low-cost expansions that can be executed quickly. UOP recently commercialized ADS-37 adsorbent and high capacity revamp for its Parex Process, enabling producers the opportunity to take full advantage of the current up-cycle. ATC, by making the right decision at the right time, was able to achieve a substantial increase in capacity just as the market was at its peak.