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FILLING THE PROPYLENE GAP – SHAPING THE FUTURE WITH ON-PURPOSE TECHNOLOGIES

Introduction

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Global demand for propylene continues to rise and the market is projected to enjoy solid growth rates for the foreseeable future. With this increase, however, traditional sources of propylene no longer meet the demand. On-purpose propylene solutions are necessary to fill the propylene gap. This paper will overview the market drivers for on-purpose propylene production. It will provide insight into the advantages of propane dehydrogenation (PDH) as the most efficient propylene production technology in general, and Honeywell UOP's Oleflex™ process specifically as the highest performing process technology available. To demonstrate how the benefits of UOP technology play out in practice, two examples are briefly described.

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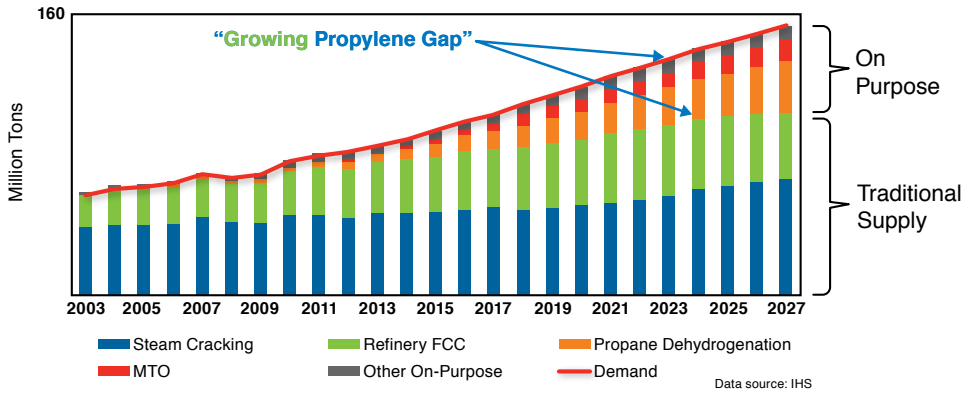
The Propylene Gap

Increasing opportunity exists for profitable production of propylene. In 2018, 68% of the end-use demand for propylene was for polypropylene. Production of this plastic is increasingly important because the growing middle class around the world, especially in developing nations, needs more plastic for consumer goods ranging from kitchen utensils and food containers to apparel, area rugs, and even car batteries. Polypropylene is a plastic that is widely considered one of the most versatile and producers of propylene as a by-product have found no end to the demand for propylene, driven by the demand for polypropylene.

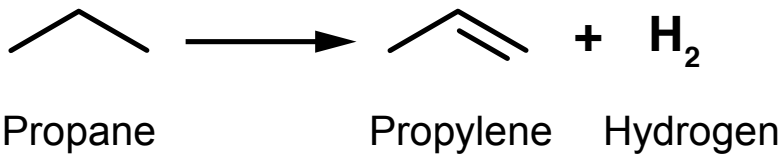
Traditional sources of propylene as a by-product have been steam cracking and fluid catalytic cracking (FCC). The growing gap between the market demand for propylene and the ability of these traditional sources to produce propylene has been widening since 2011 and is projected to continue widening. On-purpose propylene production technologies are filling the gap.

Global Propylene Production



Propane dehydrogenation is the primary on-purpose technology in use, contributing 22% of the propylene production that is filling the supply/demand gap in 2018. By 2027, the percentage is expected to grow to 32%. Other on-purpose propylene technologies include methanol to olefins (MTO), methanol to olefins plus olefin cracking (MTO + OC), and methanol to propylene (MTP). All of these options produce propylene yields that are at least double those of the traditional technologies. PDH has the highest propylene yield of all, at 85%.

PDH Has The Highest Propylene Yield



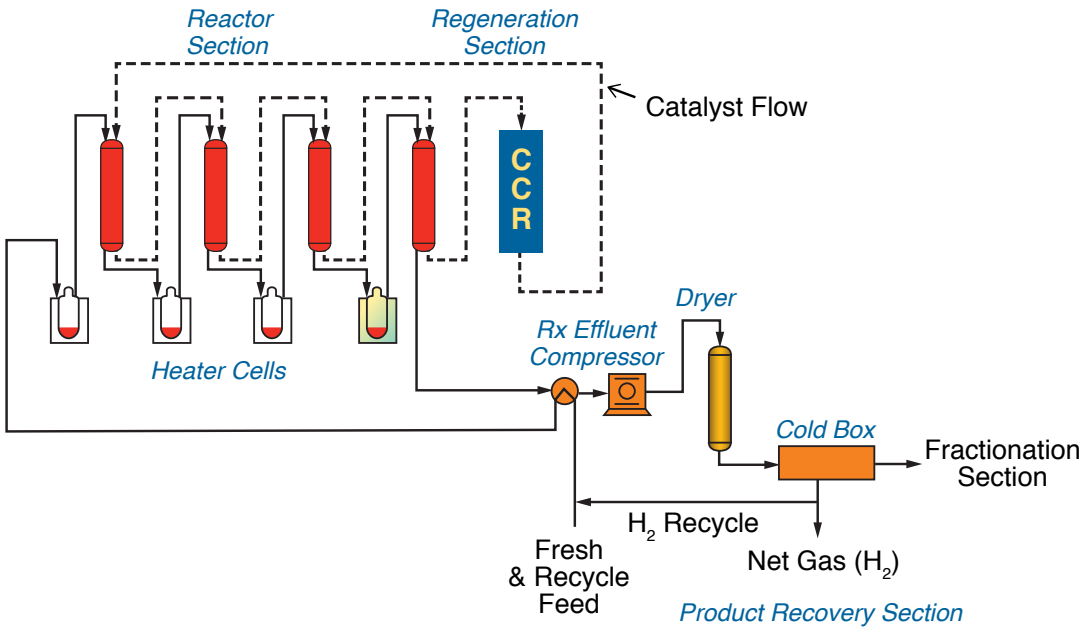
Propane dehydrogenation is a simple process with one feed (propane) that is converted to one primary product (propylene) with the option to use the by-product (hydrogen) for fuel or export for other uses. A PDH unit is easily integrated at a propane source or at a downstream polypropylene production plant. Honeywell UOP's Oleflex process is a leading PDH process on the market and will continue to hold that place due to UOP's ongoing investment building on the most outstanding expertise in the industry.

The Oleflex Process Described

A complete Oleflex unit consists of a fractionation section and reaction section. The fractionation section consists of a depropanizer that purifies propane feed to the reaction section, a deethanizer that removes lighter components from the reactor section product stream, a propane-propylene splitter, and a small selective hydrogenation reactor that removes diolefins from the propane, which is recycled to the depropanizer.

The Oleflex reaction section, which converts propane to propylene and hydrogen, is noteworthy for its steady-state operation design and small footprint. These are achieved by using an independent reactor section consisting of four heater cells with four vertical reactors, followed by an independent regeneration section. The high yield, high activity platinum-containing catalyst slowly circulates through the reactors and enters the continuous catalyst regeneration (CCR) section, utilizing UOP's well established CCR technology and enabling steady-state catalyst regeneration.

The Oleflex Process



Key benefits of the Oleflex process are lower capital expenditure (capex), lower operating expenditure (opex), better economy of scale, higher plant productivity and dependability, smaller environmental footprint, and UOP's premier project execution, technical services, and continuous innovation. Overall, the financial benefits can add up to $20 million/year lower net cost of production and an additional $80 million of NPV (net present value) and an additional 3% ROI (return on investment) compared to other PDH technologies.

Lower Capex

The streamlined design of UOP's PDH technology offers several advantages for capital expenditure. One of the main reasons the Oleflex process requires significantly lower capital expenditure is the highly active and stable nature of the platinum-containing Oleflex catalyst. With high activity, a smaller volume of catalyst is required for the same design production. With high stability, the unit can be designed to tighter parameters because catalyst deactivation is extremely predictable. Both of these factors contribute to the smaller size of Oleflex reactors when compared to other PDH technologies. Additionally, the Oleflex process is designed with positive reactor pressures. This results in a smaller, simpler reactor effluent compressor as well as smaller piping and equipment throughout the entire unit when compared to systems operating under vacuum pressure. Another key feature of the Oleflex process – the independent regeneration section – comes with the inherent benefit to capital expenditure of avoiding expensive equipment such as large isolation valves, large air blowers or drivers, a selective catalytic reduction system (SCR), or a waste water stripping system. All of these would be required for a design that relies on cyclic catalyst regeneration rather than steady-state CCR technology. Finally, Oleflex reactors are oriented vertically, resulting in a smaller plot plan that requires only 2/3 of the square footage that other PDH units require. The advantages of UOP's PDH technology can result in a 15% to 20% savings in capex.

Lower Opex

Similarly, the simplicity of design and high performance make Oleflex units simpler and less expensive to operate. The stability of the catalyst results in lower consumption of propane for the same propylene production over the catalyst life. At 90% of opex, the lion's share of operating expense goes to the propane feed, so the high product yield of Oleflex units compared to competing PDH technologies gives operators a big advantage with operating expenses. Furthermore, utility costs are minimized due to the lower compressor duty associated with positive reactor pressure, the absence of a need for nitrogen purge to seal valves, the ability to regenerate without large utility air compressors, and the absence of a steam purge. Oleflex technology boasts lower coke generation, which results in the benefits of reduced fuel or electric power requirement since no large air blowers are needed for catalyst regeneration, and more light ends (C_2-) by-product recovery for fuel or export. These opex advantages can add up to a $10/MT (metric tons) propylene production savings for a 600 kMTA (thousand metric tons per annum) propylene unit.

Better Economy of Scale

As the propylene supply/demand gap continues to widen, companies are interested in commissioning larger and larger PDH units. Whether a unit is designed for 450 kMTA, or 750 kMTA, the Oleflex process utilizes four vertical reactors, incrementally sized for the plant's designed production. Competing PDH technologies, with larger reactors, scale up by increasing to as many as double the number of reactors. For small or large applications, UOP's Oleflex process maintains the same configuration, offering the same benefits of a simple, streamlined design.

Higher On-Stream Availability and Productivity

Higher on-stream availability means higher productivity and additional profit margin to the tune of up to $10-15 million annually. This additional productivity also comes from the inherently simpler design of the Oleflex process. Independent reactor and regenerator sections allow for online catalyst changeout. There is no need to shut down the unit to change the catalyst, so unit maintenance turnarounds can be planned separately allowing plant productivity to continue during catalyst changeouts. The process utilizes adiabatic hot wall reactors. These reactors do not rely on internal reactor liners, which can be susceptible to failure, and thus avoid problems such as localized hot spots and excessive coke generation, and instead enjoy more stable operation. The positive pressure reactor design contributes to higher plant reliability by avoiding the need for hot isolation valves that can be susceptible to failure. Oleflex also achieves reliability by avoiding concerns related to valve leaks that would allow air into a system under vacuum pressure. Finally, the independent reactor and regeneration sections do not require cycling from widely different reaction to regeneration temperature modes, allowing the entire system to operate at steady state. Readers familiar with the effects of thermal cycling will comprehend the significant advantage that steady state provides to reliability—less thermal stress, less potential for equipment failure, and more time on-stream.

In addition to the reliability benefits inherent in the Oleflex process, Honeywell UOP offers the Process Reliability Advisor (PRA) as part of Honeywell's Connected Plant to further optimize plant productivity. This is a cloud-based solution to monitor and optimize process performance. It employs digital-twin plant models tuned to the customer's operating conditions as well as fault models that analyze cause and effect relationships. Data directly from the plant is securely and smartly combined with process model information to give users guidance for maximizing efficiency and reliability, being proactive on key variables, and understanding potential issues. These would include why issues might be occurring, what is impacted, and what can be done to rectify the situation. UOP experts also monitor the PRA system remotely and provide further valuable insights to help customers run most reliably and profitably between planned shutdowns.

Smaller Environmental Footprint

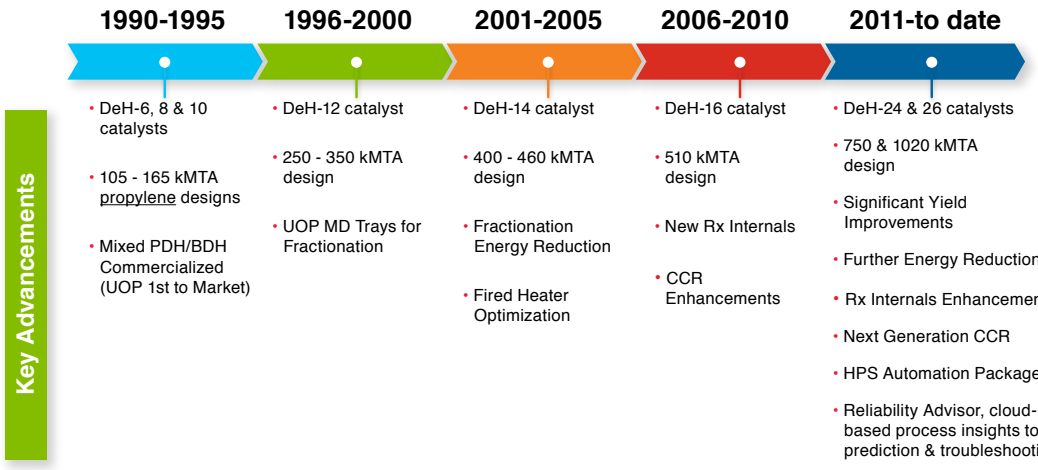
The environmental advantages of the Oleflex process are twofold, derived from the more advanced catalyst and lower process emissions. The highly active platinum catalyst itself reduces environmental impact. Compared to competing catalysts, as little as 25% of the volume of high activity Oleflex catalyst is required. This smaller amount of material directly corresponds to a smaller environmental footprint. Additionally, platinum does not require any special handling or disposal compared with other PDH catalysts, while the platinum is recoverable and recyclable. The unique design of the Oleflex process allows it to operate with significantly lower emissions. The significantly lower coke formation means there is significantly less combustion gas produced during regeneration. In the Oleflex process, this can result in five times lower NOx, five times lower NH3, seven times lower greenhouse gasses (such as CO2), and eight times lower volatile organic compounds (VOCs). No steam is added into the Oleflex process, eliminating a major source of waste water and can result in 130 times lower process waste water to be treated. Overall, Oleflex units have a smaller impact on the health of people and the environment, which is an important consideration when selecting a technology.

Superior Execution, Services, and Innovation

UOP's hallmarks include complete customer satisfaction and long-term technology partnerships in all areas of business, including their Oleflex units. UOP provides superior project execution with a world-class engineering design and commissioning experience. A fast-to-market design approach can enable startup in less than 36 months from technology selection. A UOP-supplied modular CCR is available to simplify construction. Throughout project execution, UOP experts draw on the industry's largest pool of operational experience coming from the 30 Oleflex units currently operating worldwide. UOP offers comprehensive technical services, and multiple user training programs are available, including a plant operation simulator. The Technology Services department provides early and ongoing technical support throughout the life of the plant. The Process Reliability Advisor is available as part of the Honeywell Connected Plant cloud-based services. In addition, UOP and Oleflex operators come together regularly at a UOP-hosted Users Conference and at hands-on workshops that encourage knowledge sharing and allow UOP to present new innovations as they become available.

UOP is committed to continuous technology innovation in all of its processes, including Oleflex. The record of continuous innovation for Oleflex technology spans from the initial PDH units of the early 1990s to present day, with more in development. UOP's track record of investing in catalyst innovations, increasing design capacity, operational efficiencies, and more innovations over the years, provides operators with a highly advanced and refined PDH technology.

Oleflex Technology – A Record of Continuous Innovation



The latest Oleflex catalyst innovations culminate in the newly available DeH-26. UOP's catalyst manufacturing insight and enhanced manufacturing techniques are employed in the production of DeH-26 to create a custom-designed catalyst support. Platinum content is optimized for high yields while maintaining excellent activity, ramp-up to full capacity is faster, and operators will enjoy shorter startup times, longer run lengths and increased hydraulic capacity. The key benefits of this new catalyst were designed in direct response to the needs of operators in the current market conditions. The first commercial installation is expected to go online in an existing Oleflex unit in early 2019.

The latest Oleflex process innovations that Honeywell is bringing to market are targeted to extend on-stream time. Many operators today are looking for a four-year run length, mainly to allow for synchronizing timing of planned shutdowns with other units. Operating at significantly lower temperatures reduces carbonaceous fouling which, in turn, extends run length. UOP has achieved this by further optimizing the conditions in the reactors to achieve the same conversions at lower temperatures with a lower hydrogen-hydrocarbon ratio. This way the key benefits of low opex and capex that come with Oleflex technology are maintained. A mechanical innovation providing increased open area for vapor flow with the newest reactor internals increases the unit's tolerance for fouling, further extending the time on-stream before a constraint is reached and a maintenance turnaround is required. Enhanced sulfur injection, optimized to synergize with the reactor temperature profile improvements, reduces the potential for iron sulfide fouling and further extends run length. All of these process design improvements are being incorporated into currently operating Oleflex units and these features are standard in new Oleflex designs from 2018 forward.

Leading Technology in Practice

Great things happen when an operator partners with UOP. One operator partnered with UOP to license and operate an Oleflex unit that started up over 10 years ago. The unit was designed for 350 kMTA production and achieved 100% of design. From startup through 2015, the operator worked closely with UOP to optimize their Oleflex unit operations, selectively upgrading over the years with the latest innovations that could be applied to their unit including the catalyst regeneration system, reactor internals and fired heaters. During the most recent catalyst cycle from 2015 to present, out of this close partnership with UOP, the unit routinely operated at 107% of design production capacity while using 3% lower fresh propane feed than design. The unit has achieved a higher propylene production rate at a lower operating cost due to the close partnership with UOP since startup, resulting in more than a $5 million cost of production savings over the 2015-2018 period. Additionally, when the unit was designed in 2003, the target run length between maintenance turnarounds was 2 to 2.5 years. Like many other operators, this customer is interested in extending cycle lengths and by applying select technology upgrades at the start of this most recent cycle, the unit's run length reached three years. UOP and the operator are working closely to incorporate further upgrades targeting a four-year maintenance cycle length going forward.

A different operator saw great results when implementing the Process Reliability Advisor (PRA) from the Honeywell Connected Plant. This Middle Eastern petrochemical complex with an Oleflex unit strives to operate at peak performance to improve profitability while meeting demand. PRA enabled them, in the first month, to increase process efficiency by over $1.2 million annually. Early event detection and resolution with embedded root cause analysis, the ability to operate closer to constraints and improve process performance by leveraging a digital twin of the process, and driving best operating practices led to improved compressor efficiency, improved column operations, and early warning of potential catalyst transfer issues.

Review

The gap between propylene supply and demand has motivated on-purpose propylene production since 2011. As demand continues to rise faster than supply, more units designed to produce propylene continue to be commissioned. UOP's Oleflex process is the leading on-purpose propylene production process worldwide, with more than 75% of PDH projects and nearly 80% of all propane or butane dehydrogenation projects awarded to UOP since 2011. Since 1990, nine customers have commissioned multiple UOP Oleflex units, and nine customers have switched from a competitor's dehydrogenation unit to UOP Oleflex technology for the superior performance, reliability, and profitability.

For more information

For more information, please contact your UOP representative or visit us online at www.uop.com.

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