Emissions Reduction Alberta (“ERA”)
Imtex Membranes Corp. Final Report

ERA Project ID: E0160719
Energy Efficient Propylene-Propane Separation

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Revised – January 9, 2024

Project Overview

- Start date of the Project: March 1, 2020
- Completion date of the Project: May 31, 2023
- Technology Readiness Level (TRL) at Project initiation: 5-6
- TRL at Project completion: TRL 7-8
- Total actual ERA funds received (as outlined in Contribution Agreement including holdback): $3,000,000.00

Short Project description for the ERA Website

Imtex is the technology solutions provider of Permylene, an innovative, proprietary membrane technology for the efficient extraction and purification of olefins (and other valuable chemicals). Olefins, especially ethylene (C2) and propylene (C3), are the building blocks of many important plastics, polymers, and other chemicals. As the world population grows and economies develop, the demand for olefin-based materials will continue to grow. The Permylene solution offers several applications including olefin recovery and upgrading and solves capacity constraints within petrochemical and refining processes to reduce costs and energy consumption, while unlocking additional value.

Imtex's Permylene membrane technology addresses a multi-decade-long search for an energy efficient alternative to current mainstream capital and energy intensive olefin/paraffin separation distillation processes. The target technology application is the most energy-intensive gas separation operation in the production, recovery, and purification of light olefins: ethylene, propylene and butenes, which are the predominant building blocks of plastics, rubber and chemicals.

Permylene brings significant benefits to the petrochemical industry through the efficient purification and recovery of valuable olefins, most notably: 1. Cost reductions: greatly reducing capital expenditure and operating costs (when compared to alternatives), 2. Increased feedstock utilization and 3. Yielding significant environmental benefits by lowering the energy consumption to produce olefins and reducing the volume of olefin-containing waste streams sent to flare. The technology is also able to perform separations that have, to date, been considered difficult or impractical. Permylene membrane technology meets the industry's need for a stable, high performance olefin paraffin separation process that is designed to withstand the rigors of long-term operation.

In addition to energy efficiency/debottlenecking, Permylene electrifies the olefin separation process in all applications, which otherwise requires carbon-based heat for distillation. Further, a larger-scale Imtex application can be used to electrify the separation process or support new greenfield projects.

The ERA Project demonstrated Imtex's Permylene olefin-paraffin membrane separation technology, upgrading several client feedstocks including C4 raffinates and a C2 ethylene/Nitrogen vent stream from a polyethylene reactor. Extensive C3 performance characterization testing was conducted for an industry major in support of commercial integration considerations. Purity levels from 98.0% and up to 99.9% were achieved (depending on the application, feed composition and operating conditions).

The Project also involved a phased approach to scale the commercial membrane performance using a representable system configuration and capacity in a real-world environment. The Project culminated in the commissioning of the commercial-scale 8040 membrane demonstration unit in Calgary, AB which will be used as a testing center of excellence for Imtex customers in future. Based on Imtex's sales rollout and system deployment, 93 kt CO2e and 3,933 kt CO2e emissions reduction savings are expected in Alberta, by 2030 and 2050 respectively.

Since the start of the ERA Project, the Imtex team has grown from fewer than 5 FTE to now a total team of more than 20 FTE employees, including a team in Alberta that will continue to grow. Imtex is a heavily STEM focused

organization with a high-performance team with international experience.

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Table of Contents

List of Tables

Table of Figures

Executive Summary

The Imtex membrane technology is a novel, low-cost, energy-efficient, high-purity and low-carbon technology that can supplement or replace existing distillation processes in a wide range of petrochemical and refining industries applications.

The Imtex-ERA Project objective was to demonstrate Imtex's olefin-paraffin membrane separation technology for the upgrading of light olefins using larger membrane elements to commercial readiness. The Project successfully demonstrated, via a phased approach, the scale-up of commercial membrane performance using a representable system configuration and capacity in a real-world environment. The system included all necessary integration components and technologies required to upgrade olefin-containing streams.

The Alberta 8040 system commissioned last fall and ran multiple tests to achieve up to 100-150kg/hr flow rates all while maintaining membrane integrity and demonstrating the patented hydration system. Imtex has been able to showcase the commercial build to customers, which has positively advanced both customer and strategic investor interest. Imtex has also leveraged the design and costing from the 8040 to improve our project engineering/costing accuracy, enhance design, and reduce scaling factors to subsequently larger scales. Furthermore, the Company has validated GHG emissions reductions of 63-70% compared with incumbent separation technologies - not only overall reduced energy consumptions, but also supporting clients' to shift towards process electrification and away from heat (fuel) sources for olefin-paraffin separation. Most meaningfully, this work has allowed Imtex to focus further efforts on customer engagement and field demonstrations to advance commercial validation.
Imtex's commercial validation is significantly further along than envisioned as of the end of the Project, evidenced through client projects. In January 2023, Imtex confirmed the results from an extensive 2022 testing cycle with a client, covering almost 1,000 hours of testing at 60+ conditions. In February 2023, Imtex sold an initial field demonstration system to a client in Texas. The unit has been commissioned, with numerous proposals in place for additional equipment. In other client work, Imtex conducted extensive field tests for >1500 hours. Following a successful trial, Imtex sold a technology license in March 2023.

The ERA Project centerpiece, the Alberta 8040 system, will be the "Imtex Customer Demonstration Centre of Excellence".

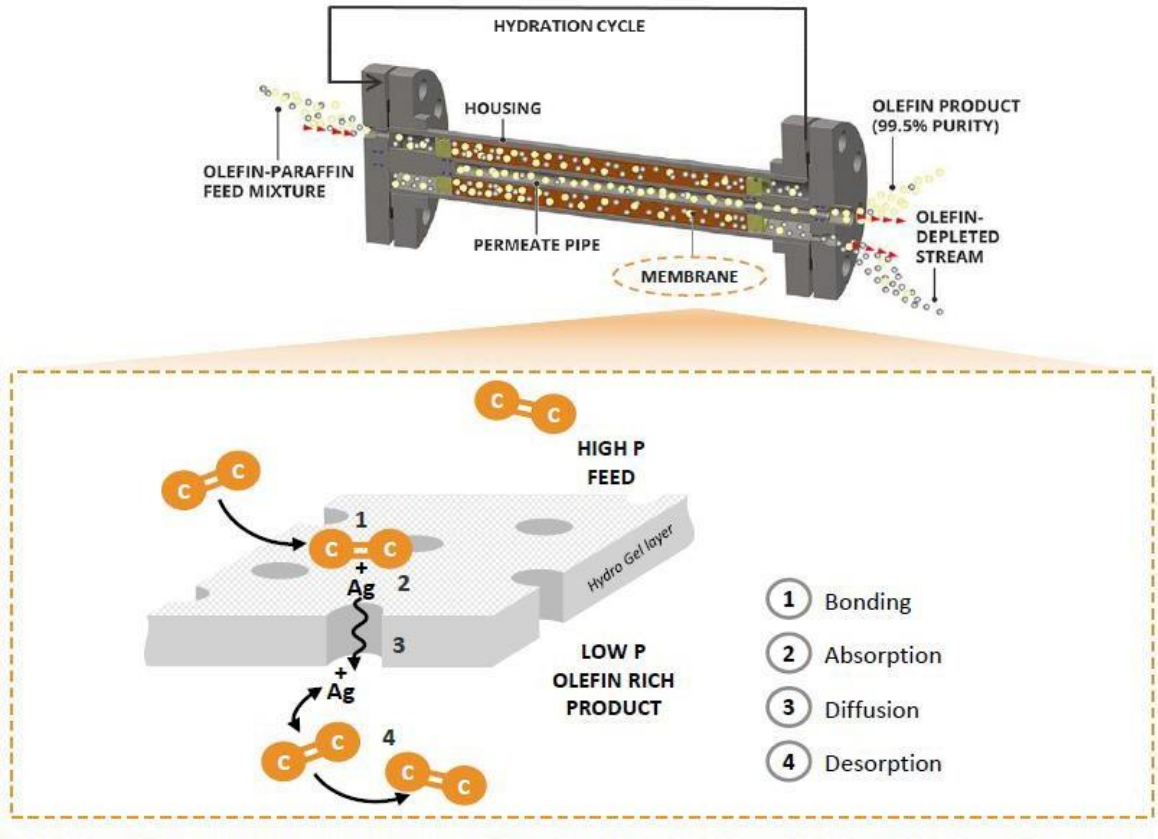
Introduction and Background

Imtex Membranes Corp. (Imtex) is headquartered in Toronto, Canada with its commercial demonstration location in Calgary, Canada. Imtex's Permylene™ technology is a membrane separation system which significantly improves olefin extraction and purification for the petrochemical and refining industries. Imtex membrane technology is currently the only commercially viable, high-performance alternative to traditional distillation techniques for olefin-paraffin separation and purification. Permylene offers a patented facilitated transport membrane and hydration system that achieves high-purity separation of light olefins (building blocks for chemicals) from associated paraffins (fuels).

The Permylene membrane technology uses silver ions to selectively transport olefins across a resilient hydrogel membrane. The images in Figure 1 show a cross-section of the membrane

system (top image) and how it works, and the selective transport process (bottom image).

Figure 1: Imtex Membrane System and Selective Transport Process



Olefins, especially ethylene and propylene, are the building blocks of many important plastics, polymers, and other chemicals. As the world population grows and economies develop, the demand for olefin-based materials will continue to grow.

Permylene brings significant benefits to the petrochemical industry through the purification and recovery of valuable olefins, most notably: 1. Cost reductions: greatly reducing capital expenditures and operating costs when compared to conventional distillation and 2. Yielding significant environmental benefits by lowering the energy consumption to produce olefins and reducing the volume of olefin-containing waste streams sent to flare. The technology is also able to perform separations that have, to date, been considered difficult or impractical. Permylene membrane technology meets industry's need for a stable, high performance olefin paraffin separation process that is designed to withstand the rigors of long-term operation.

Figure 2 below highlights Imtex's Permylene technology solution advantages. Figure 3 provides an overview of various applications of Imtex's technology within the petrochemical industry.

Figure 2: Imtex Technology Advantages

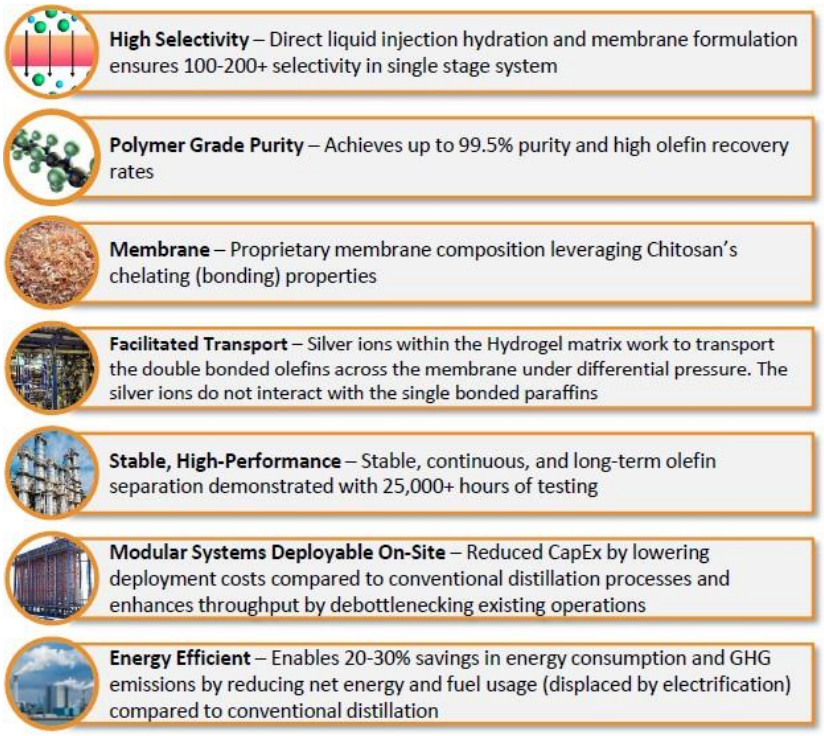
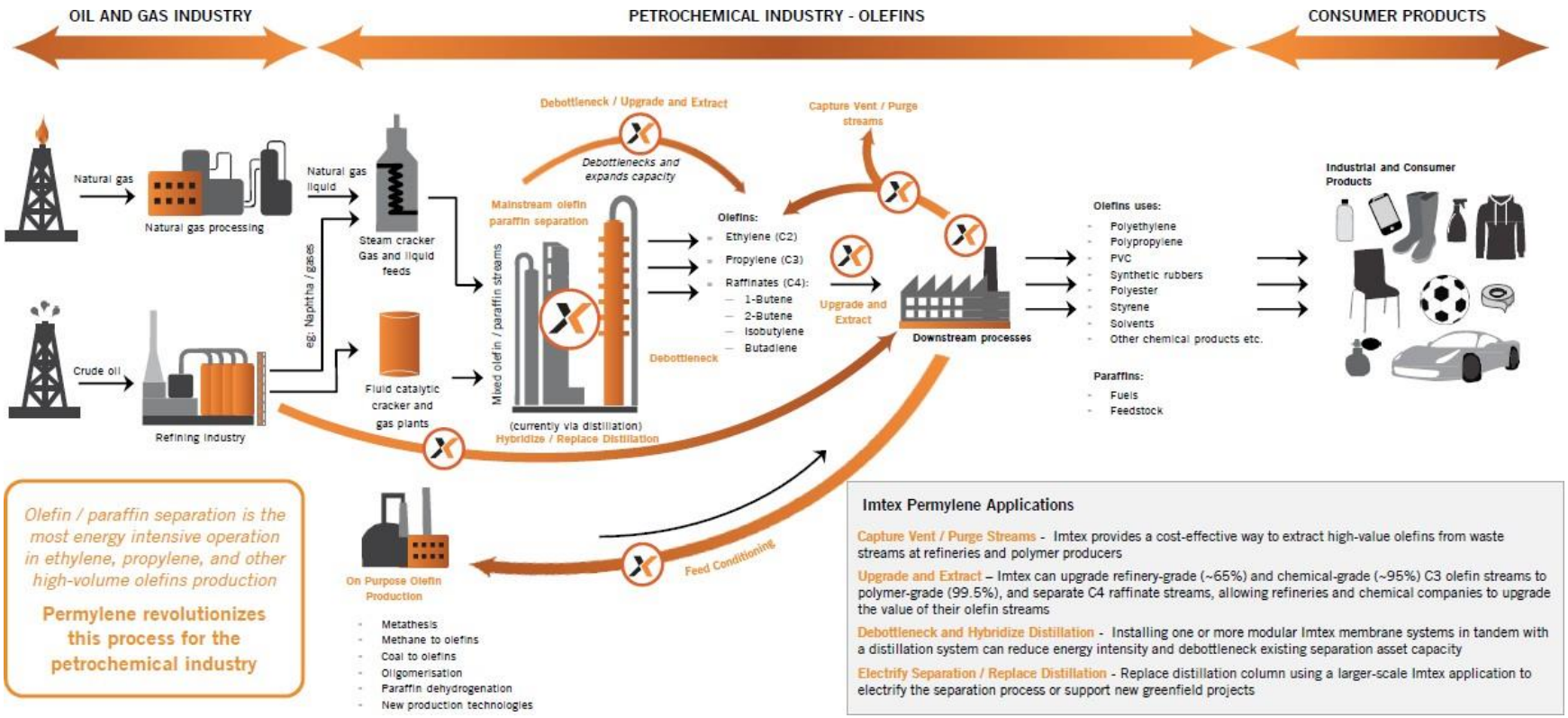


Figure 3: Permylene Offers a Comprehensive Solution



Several evolutions of the Permylene system, each incorporating design improvements and control system enhancements close to commercial system requirements have resulted in the Permylene Demonstration System (PDS). Client focused work over the past 2-3 years has led to significant improvements in system operation, parameter exploration and across a wide range of feed compositions. The Permylene technology has undergone more than 20,000 hours of operation, validating technical performance from multiple chemical producers including extensive client field tests that took place in open weather conditions in Saudi Arabia. An additional field test is underway with a client in Texas. Imtex recently also commissioned a full-scale system in Calgary, Alberta, the focus of the ERA Project.

Imtex's Permylene membrane technology addresses a multi-decade-long search for an energy efficient alternative to current mainstream capital and energy intensive olefin/paraffin separation distillation processes. The target application is the most energy-intensive gas separation operation in the production, recovery, and purification of light olefins: ethylene, propylene, and butenes, which are the predominant building blocks of plastics, rubber, and chemicals.

In addition to energy efficiency/debottlenecking, Permylene electrifies the olefin separation process in all applications, which otherwise requires carbon-based heat for distillation.

The key feedstocks are light olefin-paraffin mixtures (C2, C3, and C4). Particular to Imtex's Alberta ERA demonstration Project are the feedstocks known as refinery grade propylene (RGP) and chemical grade propylene (CGP). RGP, containing +65% propylene, is produced alongside propane at refineries or Natural Gas Liquid (NGL) fractionators. Its primary use is to be upgraded into higher grades of propylene, be it CGP, which has +94% olefin content, and polymer grade olefin (PGP), with +99.5% olefin content.

Project Description

The ERA Project demonstrated Imtex's Permylene olefin-paraffin membrane separation technology, upgrading several feedstocks from clients including C4 raffinates and a C2 ethylene/Nitrogen vent stream from a polyethylene reactor. Extensive C3 performance characterization testing was conducted for an industry major in support of commercial integration considerations.

Project Work Scope

- System Construction: the system was constructed with all process, and measurement and monitoring equipment and tested in the factory prior to deployment to its operation location in Calgary.
- System Commissioning: the system was placed on site in Calgary and commissioned in the fall of 2022.Testing: testing was performed on the system during the commissioning phase, and subsequently using synthetic feed with up to 150 kg/hr flow rates while maintaining membrane integrity and demonstrating the patented hydration system. In addition, client-trials led were conducted both at Imtex's test facility in Mississauga and in a field demonstration in another location. The stacked element has been used for purity/recovery performance demonstration.

Figure 4: Sunset Photo of Imtex's Commercial Scale 8040 Permylene System

Project Objectives

The following are the project objectives and their corresponding outcomes:

Table 1: Project Objectives

Objective #1: Scaling up to a system design and capacity which to prove Permylene in the field and ready for commercial operation. Outcome #1: The technology has been scaled to commercial capacity in Alberta that has thus far been able to demonstrate that the proprietary hydration process functions as expected. The system has run at high pressure/temperature with hydrocarbon gases. Elsewhere in Imtex field demonstrations, the technology was successfully run on client gas and achieved the target purity and recovery targets.
Objective #2: Demonstrate Permylene olefin-paraffin membrane separation technology for the upgrading of light olefins using larger membrane elements. Phased approach with the aim of scaling commercial membrane performance and readiness using a representable system configuration and capacity in a real-world environment. Outcome #2: While the 8040 system ran tests on synthetic feed, elsewhere in the Imtex testing

environment, C3 testing using commercial-length membrane elements has been run for 300+ hours, yielding as high as 99.9% olefin purity. Multiple tests were conducted with varying olefin feed concentrations on a commercial height element for a steady-state 600+ hours, achieving similar results. Tests were conducted to examine element performance given higher feed flow rate, pressure, temperature, different membrane areas and hydration factors. Imtex was able to establish commercial operating parameters for successful membrane performance (pressure, feed flow rates).

Table 2: Key Project Performance Metrics

Project Target	**Project Achievement**
Achieve polymer grade purity using 8040 element (Calgary system) Project target: 99.5%	C3: Commercial scale using synthetic mix 98.7 – 99.9% purity achieved (depending on the feed composition and operating conditions).
Achieve high recovery performance using stacked 8040 element Project target: 99.5%	Results from scaling indicate commercial-target 90% recovery can be achieved with fewer elements than originally forecast in most client cases. Membrane performance achieved through a wide range of system conditions, varying olefin feed composition, pressure, temperature, and feed flow rates.
Achieve <5% retentate in the retentate stream Project target: <10%	Imtex has learned that retentate with 5-20% olefin is a non-issue for most clients as the retentate stream is destined for recycle within the core process plant.
Performance data and extrapolated engineering supports commercial benefits Project target: Capex and opex both > 30% reduction compared to equivalent distillation system System has attractive payback in own right (i.e. > 15% IRR) CAPEX and OPEX both > 30% reduction compared to equivalent distillation system	The 8040 ran multiple 24-72hrs tests during commissioning at up to 150kg/hr hydrocarbon flow rates all while maintaining membrane integrity and demonstrating the patented hydration system. The commissioning work served to demonstrate membrane integrity including coating, seals, glues. While the 6-months of operating the 8040 has not occurred due to frozen and thereafter burst pipes (failure in heat tracing) the commissioning and early operations in the closed loop system provided invaluable findings. 1. How to overcome engineering challenges to maintain hydration system at full scale with stacked commercial elements. 2. Ensuring the pressure is maintained on a single 8x40” commercial scale element which is a key lever to show that silver circulation

	and transport will work. Further, Imtex has successfully demonstrated a commercial field test system in a real-world setting with a client (using a 2540 element). Full-commercial system Capex/Opex estimates at commercial-scale have continued to be advanced and refined using third-party software and by in-house design and process engineers.
New process patent submission / expansion of existing patents Project target: 1 – Process patent (C3) submission; 2- Expansion to existing patent (likely pertaining to hydration techniques and AgNO3 mgmt)	Imtex was successfully awarded a process patent for cross-linking its membrane which improves performance. Imtex was also successful in establishing an additional patent for a membrane multi-module housing configuration, which was customized on the basis of the 8040 system's learnings.

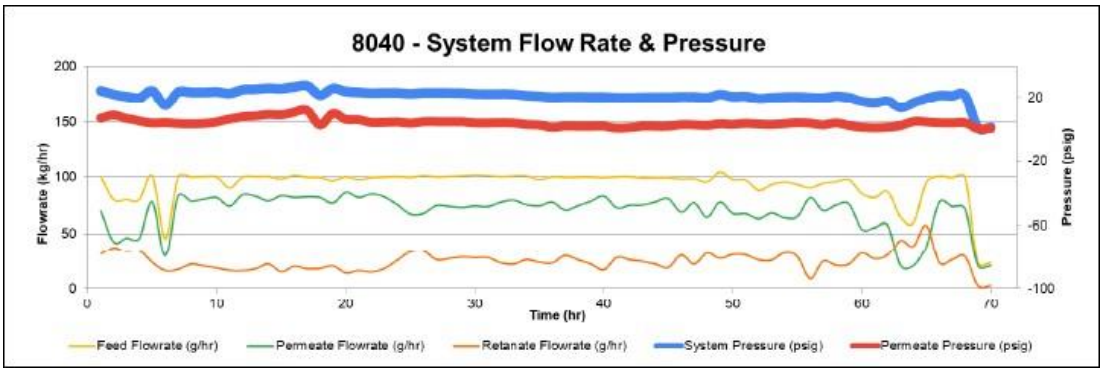
Discussion of any changes in the Project during the lifecycle of the ERA funded Project scope

At the time of writing this report, only synthetic feed was run at the 8040 commercial site in Calgary, mainly due to delays in commissioning and running the system. In the interim, several client feed field demonstrations took place elsewhere which served as important validation of the Imtex technology in commercial client operations. The key learnings from field trials will be incorporated into the Calgary 8040 system which will be used as a Customer Demonstration Centre of Excellence.

Technology Development, Installation and Commissioning Results

The Alberta 8040 system was commissioned in the fall of 2022 and ran multiple tests to achieve up to 100-150kg/hr flow rates all while maintaining membrane integrity and demonstrating the patented hydration system. Below is a representative flow rate and pressure plot for the system under initial testing with synthetic feed.

Figure 5: Representative Flow Rate and Pressure Plot for Imtex's 8040 System



The commercial scale system was tested continuously and steadily maintaining membrane integrity

for 72 hours utilizing commercial 8040 element and flow rate up to 100 kg/hr. Feed composition consisted of 50% Propylene and 50% Propane. Operation was in closed loop and hydrocarbons were condensed in product collector and returned to feed tank. Flowrates represented in “kg/hour” and

pressure in “psig”.

Imtex has been able to showcase the commercial build to customers, which has positively advanced both customer and strategic investor interest. The Company has also leveraged the design and costing from the 8040 to improve our project engineering/costing accuracy.

Furthermore, Imtex has been able to validate GHG emissions reductions – not only overall reduced energy consumptions, but also supporting clients to shift towards process electrification and away from heat (fuel) sources for olefin-paraffin separation. Most meaningfully, this work has enabled further efforts on customer engagement and field demonstrations to advance commercial validation.

Results

The Project also involved a phased approach to scale the commercial membrane performance using a representable system configuration and capacity in a real-world environment. The Project culminated in the commissioning of the commercial-scale 8040 membrane demonstration unit in Calgary, AB which will become a testing center of excellence for Imtex customers in future.

As indicated above, only synthetic feed was run at the 8040 commercial site in Calgary, mainly due to delays in commissioning and running the system. However, several client feed field demonstrations took place which served as important validation of the Imtex technology in commercial client operations.

During the project Imtex deployed two field test units at client sites for two different applications. The first successfully achieved the client’s performance requirements leading to the next stage considering the commercial unit design. The second unit was generating a product purity higher than the client’s requirement during initial testing. Testing is due to continue through 2024.

The key products are the purified olefin streams for ethylene, propylene and butene (up to 99.5% purity). A co-product is the separated ethane, propane, and butane. Purity levels from 98.0% and up to 99.9% were achieved (depending on the application, feed composition and operating conditions) during these client field trials. Imtex successfully produced propylene with 99.5% purity and a co-product of HD-5 grade propane from a synthetic, non-client feed.

Through a 3rd party study, Imtex’s GHG benefits potential was validated to be a 71% reduction (average) from the baseline case. For the Butylene system the energy use is only 0.43 MWh/tonne, a 63% reduction in energy use. For ethylene, a 70% reduction in energy use was assumed when compared to the incumbent separation technologies. With strong customer prospects, the commercial deployment in Alberta has significant potential to reduce GHG emissions associated with the olefin market.

Commercialization

Technology Advancement over the Course of the Project

Demonstrated by the results obtained and reported, commercial validation is significantly further along than envisioned as of the end of the Project. The ERA Project centerpiece, the Alberta 8040

system, will continue to be an important part of Imtex's commercialization efforts and has been positioned to prospective customers as the "Imtex Customer Demonstration Centre" with a prospective client's C3 feedstocks slated to run in Q1 2024.

Environmental Benefits

Emissions Reduction Impact

Imtex's separation technology provides a more efficient approach to the incumbent process, (fractionation and cryogenic distillation) for some applications, which is costly and energy intensive. Imtex systems require less energy than the incumbent technologies. The emission reductions arise from the avoided emissions from the avoided energy use. Compared with incumbent separation technologies, using Imtex's membrane separation technology results in 63-70% reduction in energy use. This corresponds to an average emission reduction of 0.59, 0.71 and 0.60 tonnes CO2eq/tonne of olefin in Alberta, Canada and the rest of the world, respectively. The Imtex system also reduces NO_x, SO_x, and CH_4 emissions. Imtex's GHG reductions would be substantially higher if sourced solely from green electrons. The figures below compare to average grid intensities. Incumbent applications are largely based on fossil fuel-based heat sources.

By 2045, large scale implementation of the Imtex membrane separation system is projected to result in 5.9 and 1,444 MT of cumulative GHG emissions reductions in Alberta and the rest of the world, respectively. With more than 75% of Canadian olefin production occurring in Alberta, there is a significant opportunity for Imtex to contribute to a low carbon economy in the province.

Economic and Social Impacts

Since the ERA Project's inception, the Imtex team has grown from fewer than 5 FTE to a total team of nearly 20 FTE employees. We expect to continue to grow the Alberta team by up to 10 additional employees to fulfill planned customer long-term trials by 2025 which is expected to grow to 15-20 by 2030.

The ERA Project has contributed Innovation capacity in Alberta through the addition of skilled personnel added in Calgary, engagement of many local tradespeople and consultants, R&D, and technology advancements including the enhancement of Imtex's IP portfolio in strategically important areas related to membrane separation in the petrochemical sector.

Scientific Achievements

Imtex was awarded two patents and submitted a third patent over the duration of this project. These patents further strengthen Imtex's technology leadership and commercialization position. Over the duration of the project, Imtex gained further expertise for how to optimize the potential operation of the Permylene system.

Communications Plan

During the Project, Imtex communicated about the progress of the build of the 8040 commercial demonstration in Calgary, as follows:

- Pictures and construction updates were shared via LinkedIn and via Imtex's website for broad communications to audiences (existing customers, customer prospects, broader cleantech and petrochemical ecosystems).

- Imtex was featured by Zeton (Imtex's key equipment and module fabricator) in their newsletter for customers and clients.
- Imtex communicated Project progress to its employees, Board members and investors regularly via regularly scheduled meetings and email communication.

Plans for Communicating Information about the Project, Project findings, and Results or the Underlying Technology with Third Parties.

Now that the Project has been completed, Imtex will work with ERA to disseminate non-confidential key Project successes and achievements with important stakeholders that will promote Imtex's capabilities and ERA's significant Project contribution which has enhanced innovation, economic, and environmental benefits and capacity in the province.

- Key Messages:
    - Key Project Successes/Achievements – High purity levels achieved, GHG emissions reductions, cost savings (CAPEX, OPEX)
    - 8040 Commercial Scale Demonstration as Imtex's Permylene technology centre of excellence for client field trials.
    - Alberta employment, economic, environmental benefits
- Key Audiences: Alberta, Canada, global client prospects; existing clients; Cleantech ecosystem. Petrochemical sector ecosystem, internal – employees, Board members, etc.
- Key Communications Tools and Platforms:
    - Verbal and Email Communications: Imtex staff, Board, current clients, client prospects
    - LinkedIn: All audiences
    - Imtex, ERA Websites: All audiences
    - White papers: Petrochemical ecosystem, cleantech ecosystem, client prospects

Overall Conclusions

Imtex fabricated and commissioned the commercial- scale 8040 system in late 2022 in Calgary, AB. This commercial system provides prospective customers with a unique opportunity to run their own feedstock prior to purchasing their own commercial Permylene system. The system has a design flow rate of up to 700 kg/hr and has successfully completed an initial series of pressure tests, with a prospective client's C3 feedstocks slated to run in Q1 2024.

The commercial demonstration system is designed for customer feedstock trials to demonstrate polymer grade purity (99.5%, 97.5%) and recovery (80-90%) targets on the C3 and C4 hydrocarbons feedstocks, respectively. The demonstration system is a modular building block for further commercial systems of any size. Validating polymer grade purity and recovery levels at commercial scale further Imtex's business development opportunities with energy and chemicals companies.

The Project demonstrated Permylene olefin-paraffin membrane separation technology for the upgrading of light olefins using larger membrane elements which have more surface area for increased throughput. This was demonstrated in both client field trials and with the commissioning and operations of the commercial scale 8040 demonstration system in Calgary, Alberta. The Project involved a phased approach with the aim of scaling commercial membrane performance and readiness using a representable system configuration and capacity in a real-world environment. The system included all necessary integration components and technologies

required to upgrade olefin containing streams. The project progressed Permylene from a TRL 5-6 to TRL 7-8.

Next Steps for the Technology/Process/Innovation, including Potential Follow-Up Projects

Imtex continues to engage with several clients within Alberta that can benefit from the technology. In addition, Imtex has identified further opportunities at existing facilities and in consideration of the future Petrochemical direction for Alberta. Imtex will continue to utilize the 8040 system as a testing and demonstration centre, based in Alberta.

To learn more about the benefits of Imtex's membrane separation technology, reach out to Jamie Hughes, VP of Business Development at jhughes@imtexmembranes.com or phone +1 (905) 363-0111 and visit www.imtexmembranes.com