Anhydrous Ethanol Production Using Membrane Technology

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- INTRODUCTION -

Background

Fuels are an essential, irreplaceable energy source known for their reliability and energy density that has helped fuel travel industries and expand our traveling capabilities. With the impending impacts of climate change and goal to limit global warming to 1.5 degrees C, it has become crucial to reduce our reliance on fossil fuels and adopt renewable energy sources.

The transportation sector consumes approximately 10% of global greenhouse gas (GHG) emissions. A current common practice to tackle this significant issue is to blend anhydrous ethanol (>99.5 wt%) into gasoline to increase its octane rating and reduce emissions. However, ethanol-water mixtures form an azeotrope at 95 wt%, making it difficult to further purify using conventional distillation to reach the desired purity and produce anhydrous ethanol. The most widely used method to dehydrate ethanol in Brazil is azeotropic distillation using cyclohexane as an entrainer, an energy-intensive process with major safety and environmental concerns, due to concerns of toxicity and adverse human health effects from cyclohexane exposure.

The Issue

To design a process that completely replaces azeotropic distillation that is more energy-efficient, safer, and environmentally responsible, the process utilizes Whitefox membranes to produce anhydrous ethanol at 99.3 wt%. The distillation unit in our process uses vapor injection from the sugar pre-evaporation process instead of distillation columns, results in a comparative simplistic design with fewer equipment in membrane dehydration systems.

Our Solution

Our solution is to design a process to completely replace azeotropic distillation which is more energy-efficient, safe, and environmentally responsible. The process utilizes Whitefox membranes to produce anhydrous ethanol at 99.3 wt%.

- PROCESS OVERVIEW -

Plant Location: São Paulo State, Brazil

Operational: 180 days/year, May-October

Production Capacity: 230 m³/day anhydrous ethanol

- FINDINGS -

Dehydration Techniques: Membranes VS Cyclohexane

As summarized, the Whitefox membranes show extended benefits in terms of economics, safety, and operability. This is due to multiple factors:

- The higher equipment cost for dehydration using cyclohexane entrainer (~$3 million USD) can be attributed towards the material of equipment required due to the toxic properties of cyclohexane. Additionally, cyclohexane entrainer systems call for a more complex plant layout with additional equipment (distillation columns, recovery columns, etc.) in comparison to the Whitefox membrane, which utilizes fewer equipment.

- Membrane dehydration shows lower cost of production ($0.51 USD/L) mainly due to the evident difference in energy and steam consumptions. Moreover, membrane dehydration systems are simpler to operate and maintain than cyclohexane entrainer systems. The evident difference in energy and steam consumptions is due to the comparatively simplistic design and fewer equipment in membrane dehydration systems.

ETHANOL MARKET TRENDS

These Ethanol market trends observed are caused by various social and legislative acts implemented in the past and recently. Notably:

- Canadian Net Zero Emissions Accountability Act - passed in 2021
- Brazilian mandate to blend Ethanol into fuel supply - passed in 1999

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