SIMULATION AND OPTIMIZATION OF THE PRODUCTION OF CUMENE (ISOPROPYLE BENZENE)

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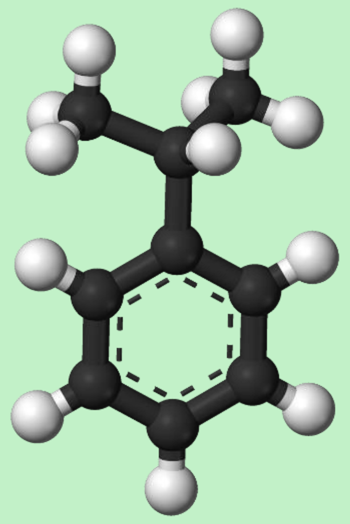
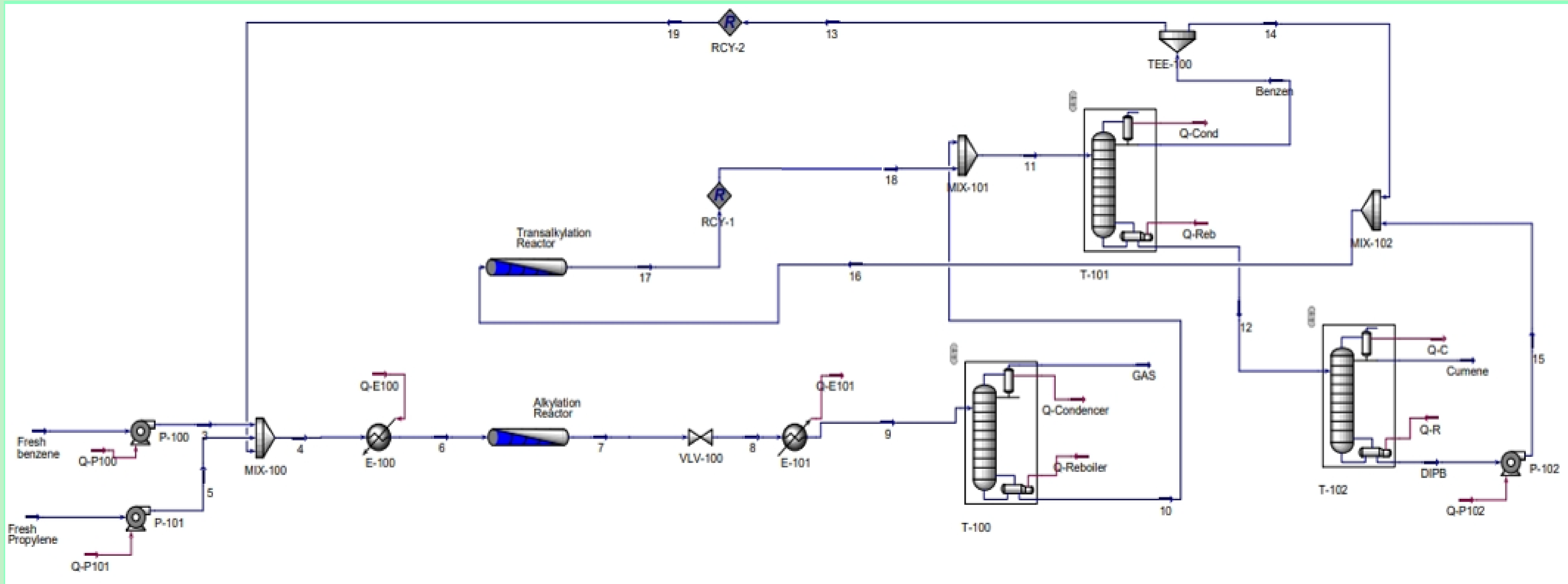
ABSTRACT

Cumene (C_9H_{12}), is produced via the alkylation of benzene with propylene and transalkylation of DIPB with benzene. The process uses two liquid-phase high-pressure reactors: the alkylation reactor (8.16 m³, 4896 kg catalyst) and the transalkylation reactor (0.61 m³, 366 kg catalyst). The design targets an annual production of 120,000 tons per year. Three distillation columns were designed using shortcut methods. Equipment design includes heaters, coolers, and control systems. HAZOP analysis was conducted, and economic evaluation showed a total capital investment cost of $6.32 million with a 4-year payback period and 18.79% rate of return.



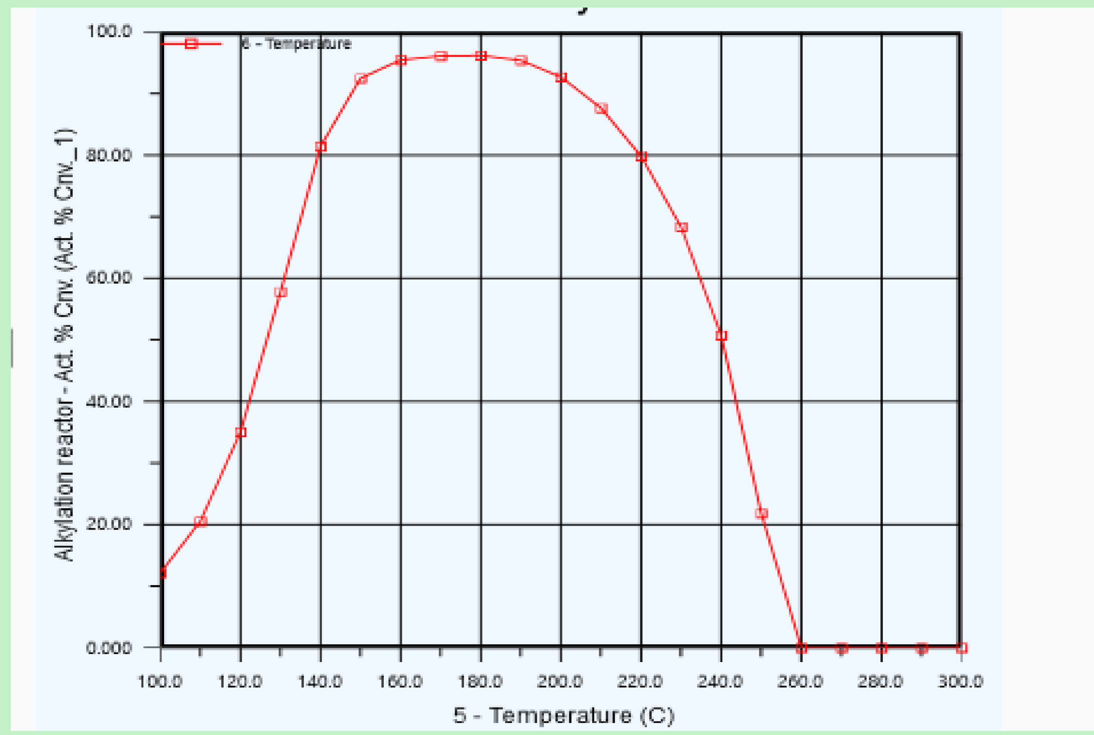
PROCESS DESCRIPTION

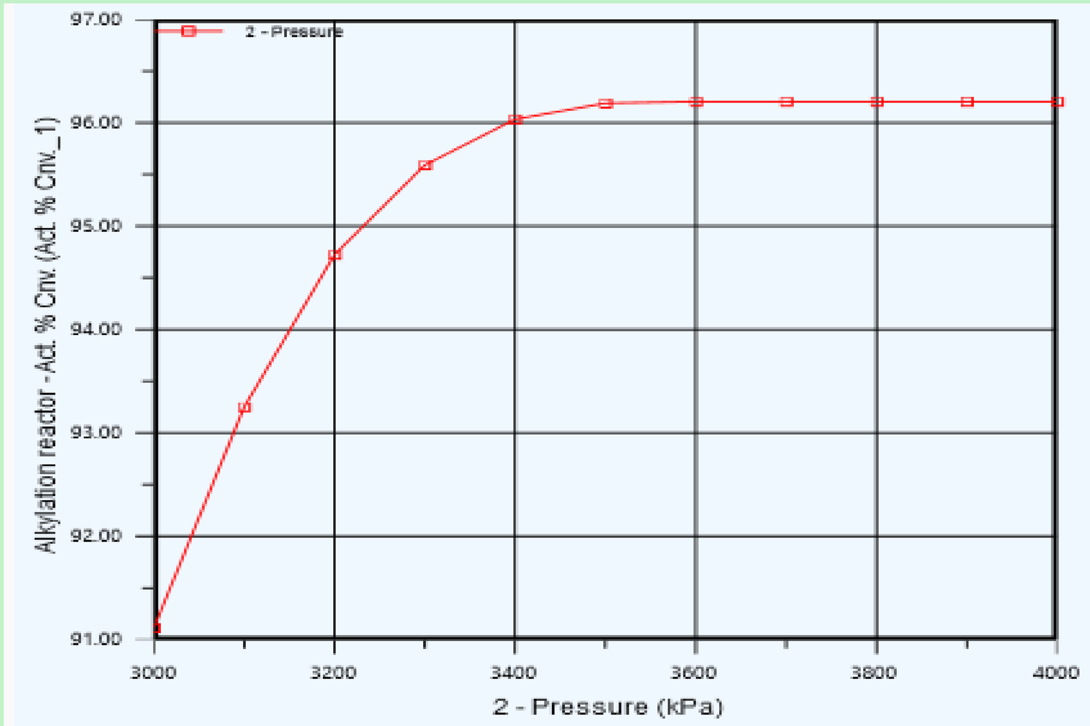
Fresh benzene and (95% propylene and 5% propane) are mixed with recycled benzene and heated to 150–200 °C under high pressure before entering the alkylation reactor (R-101). In this reactor, cumene and DIPB are formed. The reactor output is sent to the first distillation column (D-101) to remove propane. The remaining mixture is sent to the second column (D-102) to recover benzene, which is recycled. The third column (D-103) separates cumene (≥99%) from DIPB. The DIPB is then fed to the transalkylation reactor (R-102) to produce more cumene, improving overall yield.



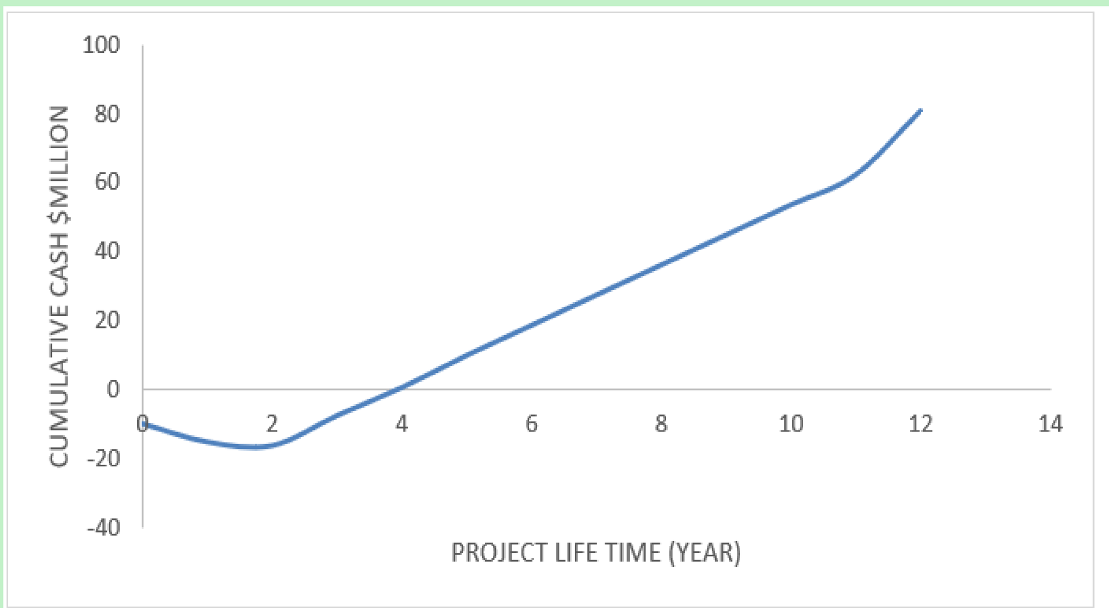
OPTIMIZATION

To improve the efficiency of the cumene production process, optimization studies were performed using Aspen HYSYS. These studies aimed to maximize the conversion of propylene in the alkylation reactor and enhance the production and purity of cumene.

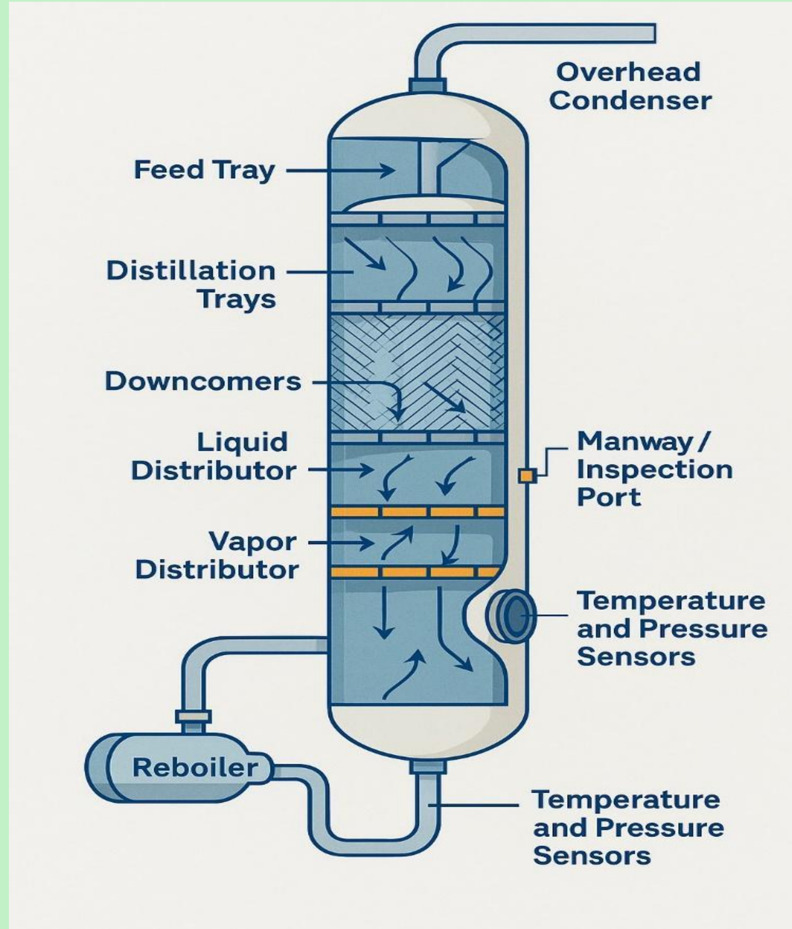




CUMULATIVE CASH FLOW DIAGRAM



DESIGN



Summary of Cumene Distillation Column [T-102]

Feed condition	Saturated liquid (q = 1)
Minimum reflux ratio	0.2363
Actual reflux ratio	0.3072
Minimum number of stages	7
Theoretical number of stages	18
Theoretical feed stage	8
Efficiency	47.8%
Actual number of stages	36
Actual feed stage	16
Tray type and plate material of construction	Carbon steel sieve trays
Column height	19.2 m
Column Diameter	1.482 m

Scan the QR code for more details

CAPITAL COST

Unit Type	Equipment Code	Equipment Cost ($)
Heat Exchangers	H-100	151,000
	H-101	139,000
	H-102	137,000
	H-103	223,000
	H-104	121,000
	H-105	272,000
	H-106	121,000
	H-107	323,000
Towers	T-101	196,000
	T-102	760,000
	T-103	315,000
Vessels	R-101	213,000
	R-102	34,800
Pumps	P-100	77,300
	P-101	205,000
	P-102	61,000
Total Capital Cost		3,349,200

CONCLUSION

In this project, we successfully simulated and optimized the cumene production process using Aspen HYSYS. The design incorporated both alkylation and transalkylation reactors to enhance propylene conversion and minimize the formation of byproducts such as DIPB. Through rigorous material and energy balance calculations, equipment design, and process simulations, we achieved our target cumene purity of 99.5% and an annual production capacity of 120,000 tons per year, The process design included detailed reactor modeling, distillation column sizing, and heat exchanger design. A control strategy and HAZOP analysis were implemented to ensure safe and stable plant operation. Economic analysis demonstrated the project's feasibility, showing a total capital cost of $6.32 million, a payback period of 4 years, and a return rate of 18.79%.The optimization studies revealed that the transalkylation reactor significantly improved the overall efficiency by recycling DIPB back to cumene, which reduced waste and enhanced economic returns. This not only supports sustainable industrial practices but also aligns national goals for energy and industrial leadership, Overall, this project reflects a comprehensive approach to chemical process design, integrating technical accuracy, safety, and environmental responsibility. It serves as a strong foundation for future work and potential industrial application.