

BENCH-SCALE PSA FOR OXYGEN & NITROGEN SEPARATION

JOURDAN ALLEN & JACOB SNOW

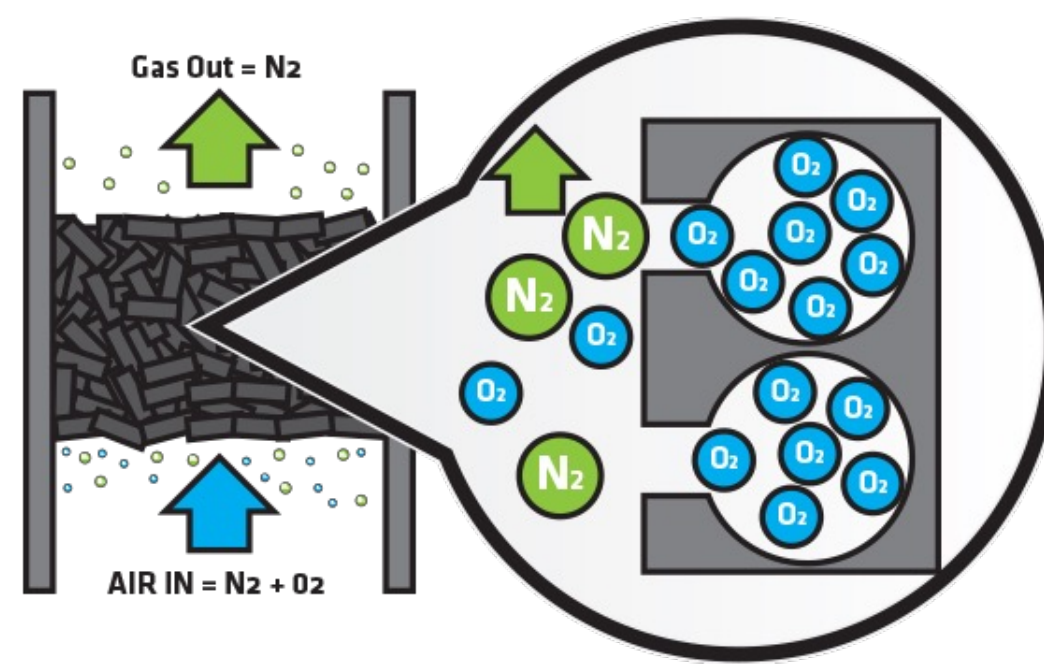


Project Objectives

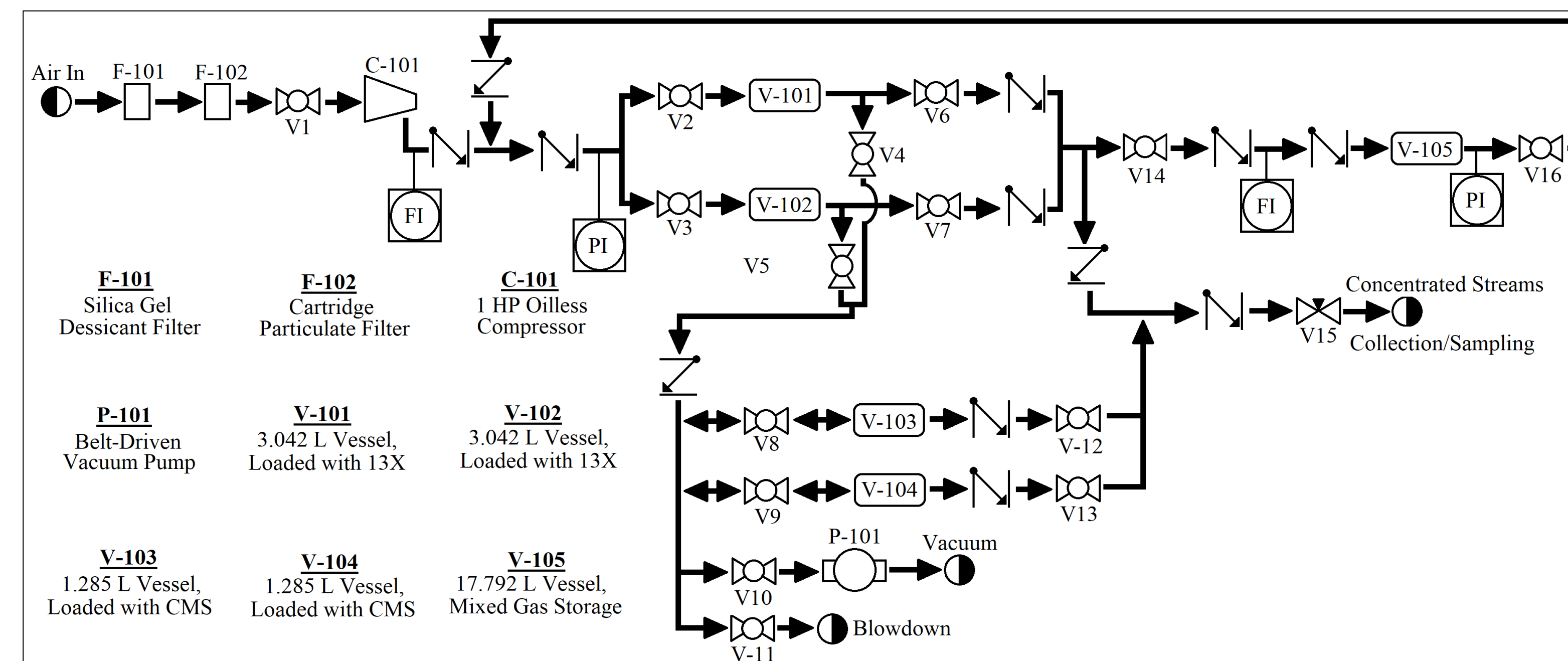
- Design a bench-scale pressure swing adsorption (PSA) system for senior ChE separation process labs capable of producing:
 - Oxygen purity 99% at 0.5 LPM
 - Nitrogen purity 99.9%
- Determine operational conditions
- Develop operational procedure
- Full scale-up for medical grade oxygen production plant with 1000 LPM capacity

Background PSA Systems

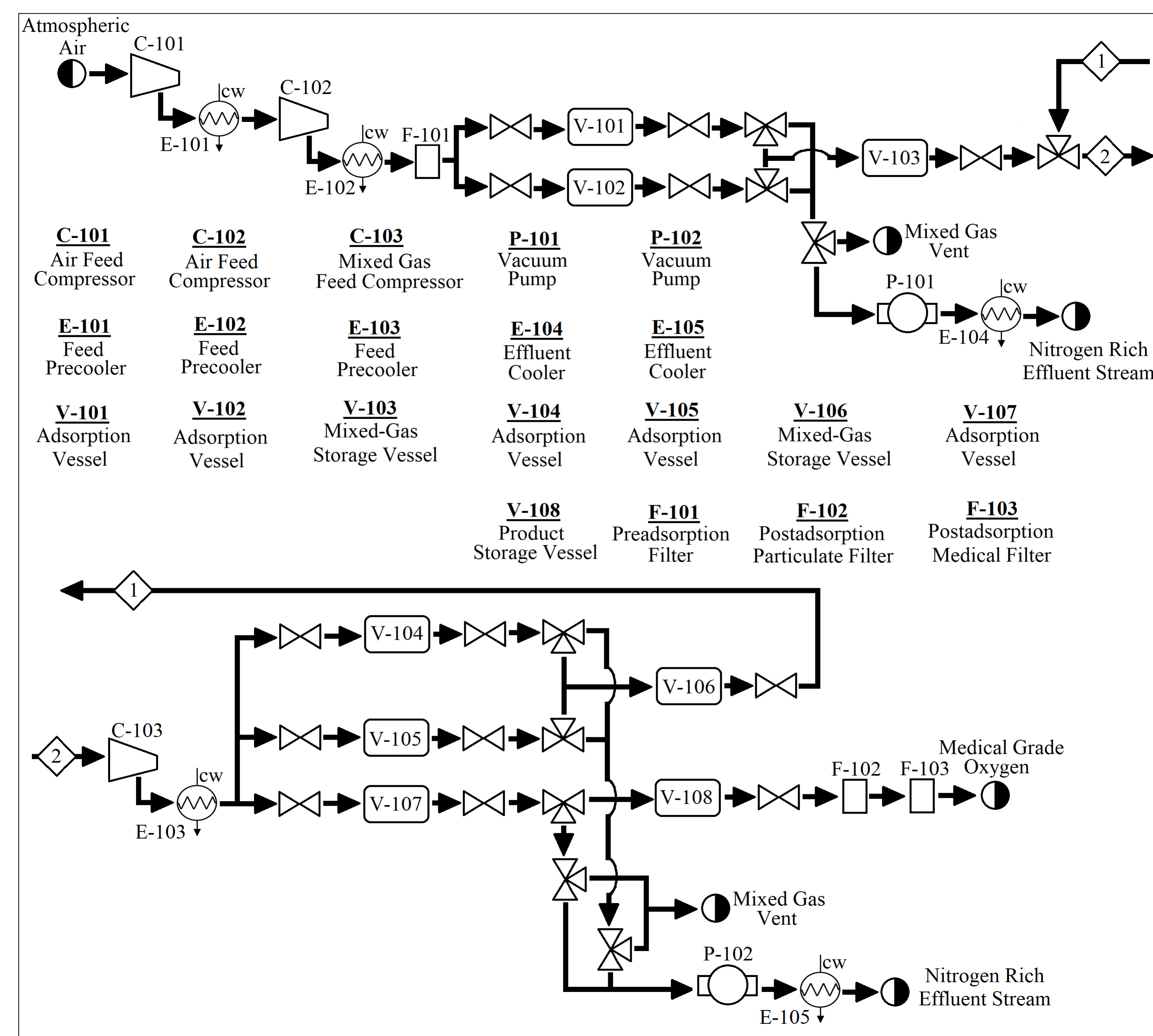
- PSA is a separation technique used to produce high-purity product streams from gas mixtures.
- Gaseous species are separated using porous beads or pellets known as adsorbents.
- Gas species that is adsorbed or stuck on surface of adsorbent is known as the adsorbate.
- Adsorption of adsorbate occurs at high pressures; desorption of adsorbate occurs at low pressures as a result of pressure drops or pressure swings.



Bench-Scale System Configuration PFD



Full-Scale Process Design PFD



Results

- Single-pass cycle:
 - Operational pressure range 120-90 PSIG
 - O₂: 66.9 ± 0.1 mol % at 0.65 ± 0.01 LPM
 - N₂: 87.4 ± 0.1 mol% at 0.31 ± 0.01 LPM
- Double-pass cycle:
 - Operational pressure range 120-40 PSIG
 - O₂: 90.3 ± 0.1 mol % at 0.55 ± 0.01 LPM
 - N₂: 87.2 ± 0.1 mol% at 0.20 ± 0.01 LPM

Economic Analysis

- The scale-up facility was designed based on data from the bench-scale PSA system
- Literature data and heuristics were implemented to develop the economic analysis.

Capital Investment & Expenses	
Fixed Capital Investment (FCI)	\$12.3 million
Cost of Manufacturing (COM _d)	\$5.4 million
Working Capital (WC)	\$2.5 million
Revenue	
Revenue (Offset Cost)	\$9.7 million
Profitability	
Payback Period (PBP)	2.93 years
Cumulative Cash Position (CCP)	\$69.0 million
Rate of Return on Investment (ROROI)	26.93%

Conclusion

- Upgrading fittings and piping to metal, vacuum rated components and implementation of an electronic control system, with more robust data measurement systems, would improve learning potential through system operation.
- The economic analysis shows the scale-up facility is a financially feasible and cost-effective method to generate medical grade oxygen.



Acknowledgements: Advisor: Dr. Matthew Bernards | Sponsor: Dr. David MacPherson
Department of Chemical & Biological Engineering



2023 Capstone Project