

Modular Distributed Ammonia Synthesis

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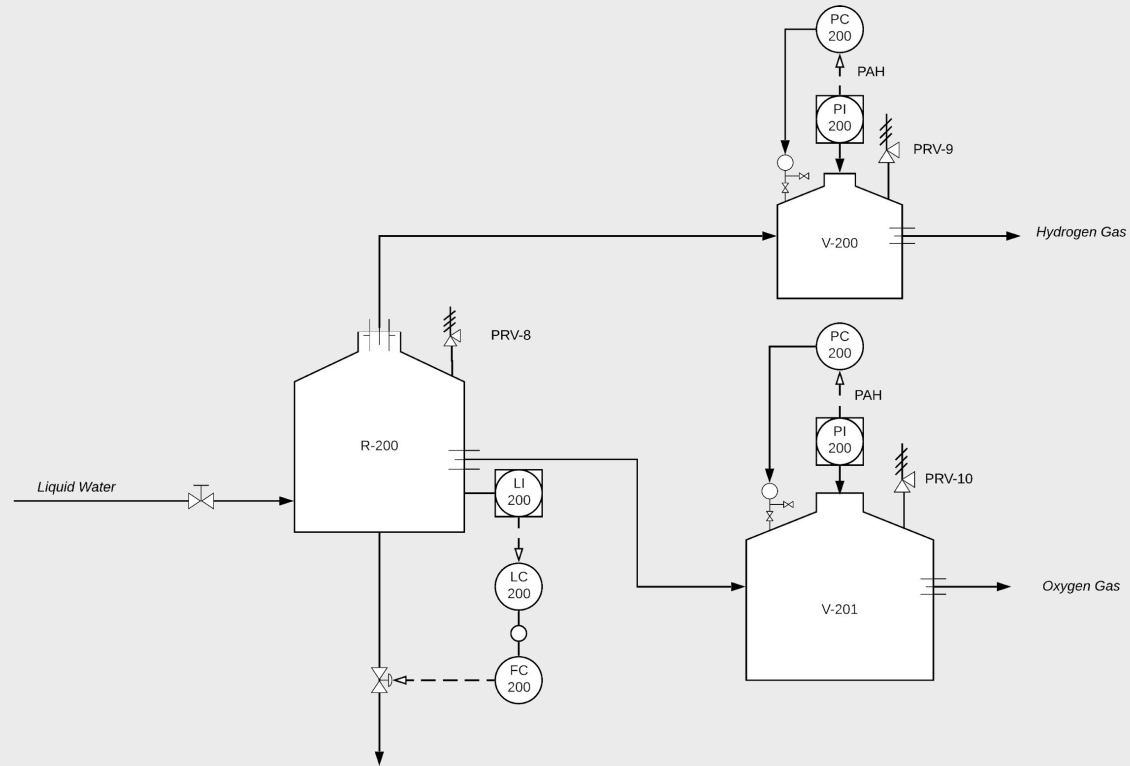
Background

- Ammonia used to produce food for half of the global population
- Ammonia manufacturing accounts for 1-3% of the world's energy consumption, 5% of the world's natural gas consumption, and a significant portion of greenhouse gas emissions
- Ammonia is mainly used in the production of fertilizer
- Since it is a toxic and flammable gas, ammonia is very expensive to transport

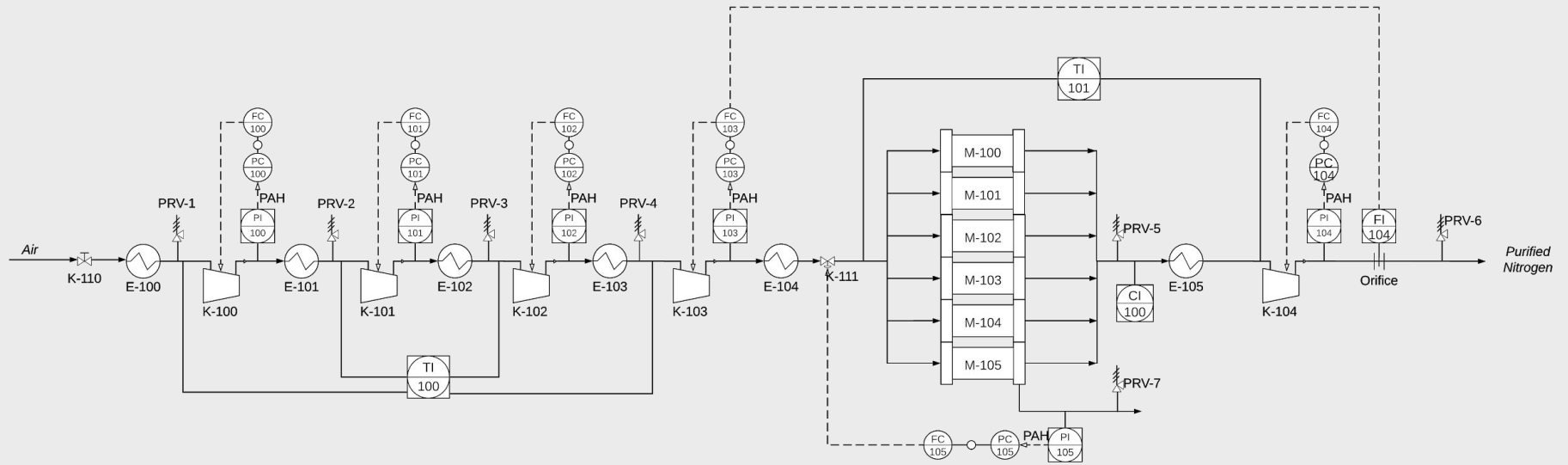
Design Requirements

- Plant must be able to produce 50 metric tonnes per day of commercial anhydrous ammonia
- Anhydrous ammonia must have a purity of 99.5% by mass
- Ammonia is produced and stored as a liquid at high pressure
- Ammonia is produced from nitrogen and hydrogen intermediates
- Design must employ new modular manufacturing methods
- Minimize the carbon footprint of the plant
- The plant will be located in the Minnesota River Valley

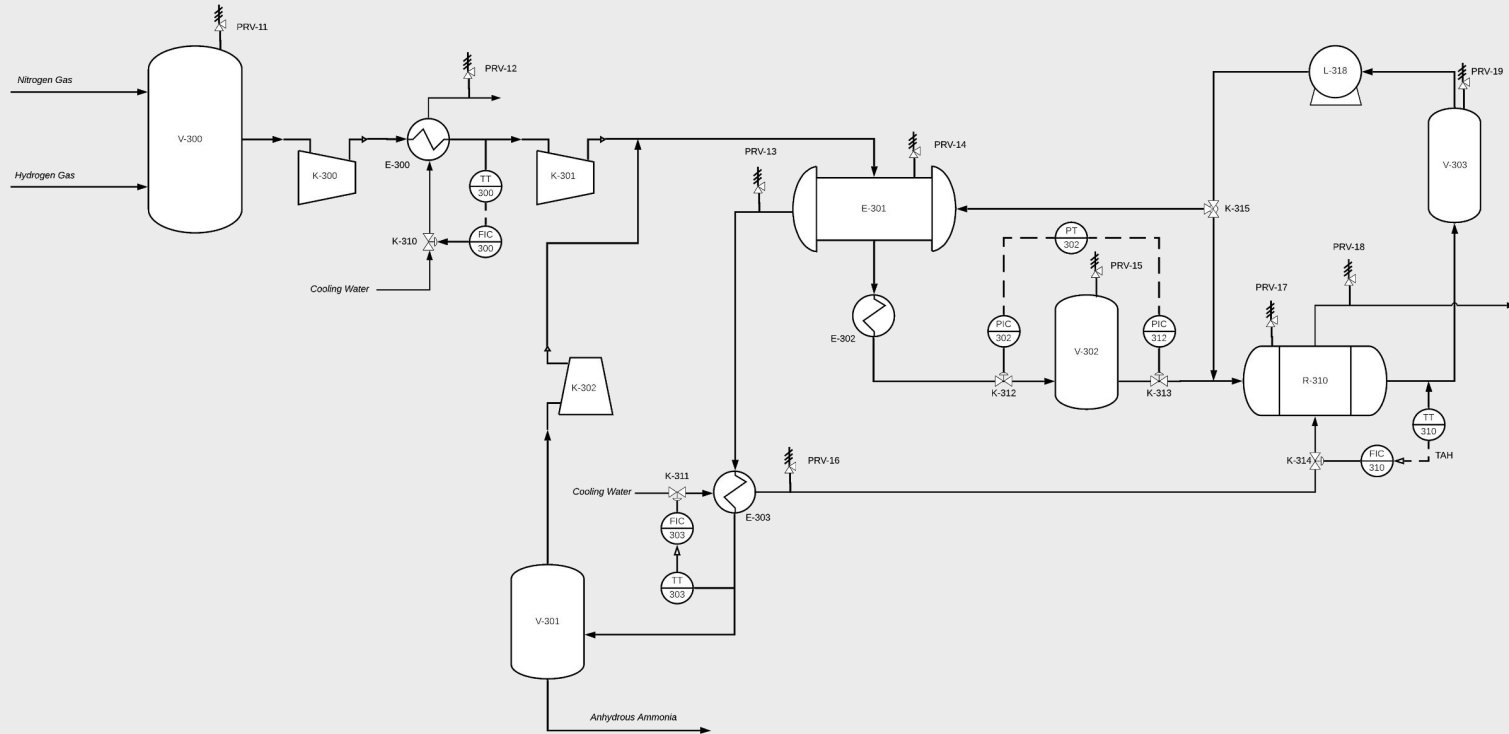
Hydrogen Synthesis



Nitrogen Purification



Anhydrous Ammonia Synthesis



Safety, Health, & Environmental Considerations

- Modular design allows easier transportation due to smaller loads
- Smaller quantities produced
- Potentially dangerous chemicals
 - Nitrogen gas can cause suffocation
 - Oxygen gas can lead to fires or explosions
 - Ammonia vapor can be toxic
 - Hydrogen gas can lead to explosions
- Thorough process safety and proper training is required to ensure the safety of users
- Potential risk of contaminating waterways
 - Need to ensure plant is not located near major sources of ground water or rivers
- Uses wind power
- Reduced export distance which reduces the use of fossil fuels in transportation

Economics

Given ammonia's substantial energy consumption, all energy requirements for the three major units processes (N₂ and H₂ separation and the ammonia synthesis) will be derived from wind power.

- (1) Single Module Unit - 5 MTPD
CAPEX: \$13.7 million
Unit Cost: \$5050.26 per MT
IRR: 47%

- (2) 10 Modules - 50 MTPD
CAPEX: \$ 86.8 million
Ammonia Unit Cost: \$4091.43 per MT
IRR: 64%
- (3) 10 modules with Turbines:
CAPEX: \$108.5 million
Ammonia Unit Cost: \$1658.13 per MT
IRR: 15%

Conclusion

- Market price of anhydrous ammonia is \$550 per MT
- Labor costs are the highest expenditure
- Even at good IRR, unit prices not market competitive
- The plant designs are not economically/financially viable

Acknowledgments

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AICHE Design Competition Committee

Thank You!