COLLEGE OF ENGINEERING

Chemical, Biological, and Environmental Engineering

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

Acknowledgments

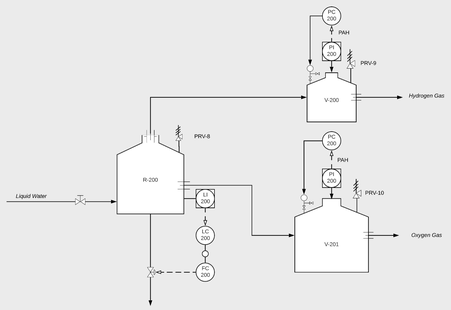
Nick AuYeung

Natasha Mallette

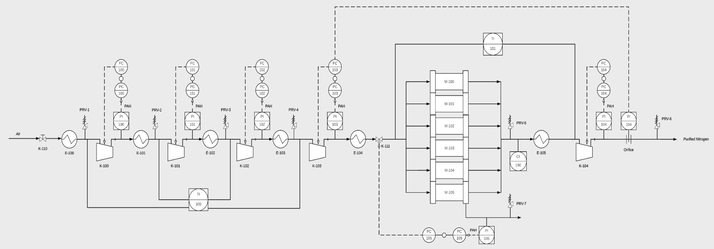
AIChE - Design Competition committee

Process & Instrumentation Diagrams

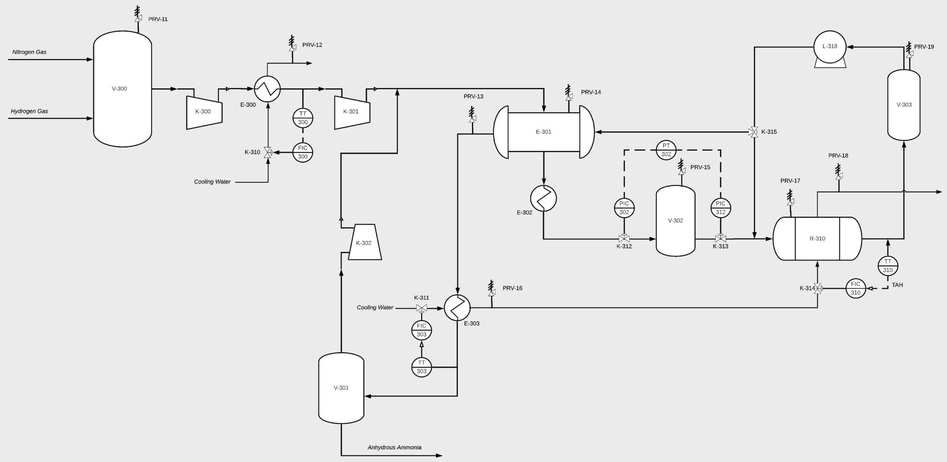
Hydrogen Production



Nitrogen Separation



Ammonia Production



Other Design Considerations

Steam Methane Reformation

- produces large amounts of H_2 gas through the water -gas shift reaction
- Inconsistent with the AIChE problem statement desiring wind powered ammonia production
- The efficiency of the process is reduced with decreasing size making it incompatible with the modular design process

Non-thermal Plasma reactors

- Non-thermal Plasma reactors create ammonia from room temperature and pressure feed gas making it an inherently safer process
- Scaling-up from lab scale reactors causes a drop in efficiency because ammonia is decomposed by the plasma
- This process is prohibitively energy intensive producing 1 gram of ammonia per kilowatt hour

Safety & Health

- 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

Environmental Considerations

- 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
Ammonia 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%