Carbon-Free, Modular Ammonia Plant

Project Objectives

- Develop a five-module ammonia production plant capable of producing 50 metric tons per day used as fertilizer
- Design a carbon free ammonia production plant using 100% wind energy built in the Minnesota River Valley
- Submit preliminary design recommendations to student AICHE chemical plant design competition

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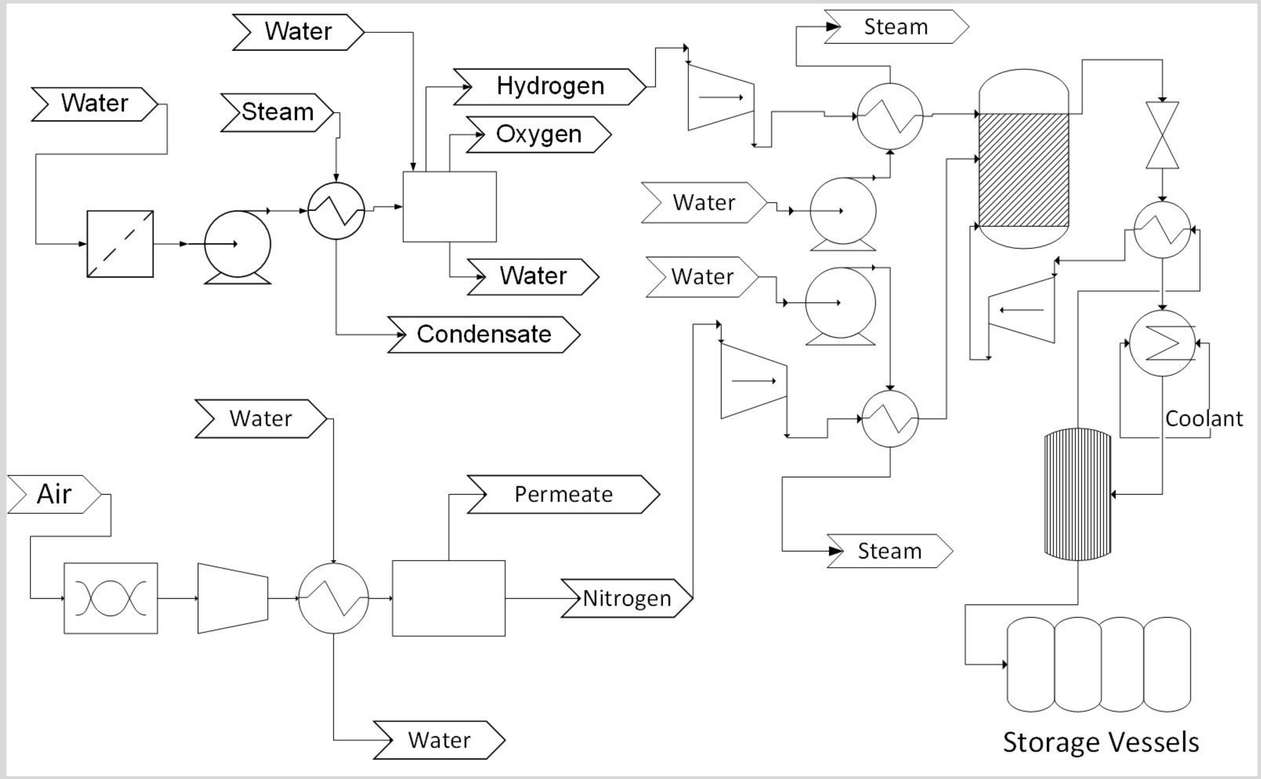
Unit Operation Summaries

Section 1 – Electrolysis for Hydrogen Gas Production

- Alkaline (KOH) electrolysis cells used in parallel (monopolar).
- Pure nickel mesh electrodes, increased surface area.
- Cube-shaped systems, each producing 43 kmol/hr of pure hydrogen.

Section 2 – Membrane Separation of Nitrogen from Air

- T(p-OCH_3)PPCoCl membrane used for removing oxygen from air to produce a purified nitrogen stream



Section 3 – Ammonia Synthesis Reactor

- Ru-based catalyst for high conversion at low P (86 bar) and T (380 °C).
- Catalyst-filled, multi-tube design with axial-radial flow gives low pressure drop and small footprint.

Section 4 – Ammonia Separation with Flash Drum

- Rapid temperature decrease to isolate liquid ammonia

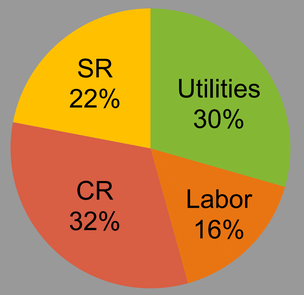
Section 5 – Liquid, Pressurized Ammonia Storage

- Cylindrical vessels (2.5 m x 7.5 m) constructed with 316 stainless steel.
- 200 psia operating conditions, MAWP specified as 250 psig.

Cost Summary

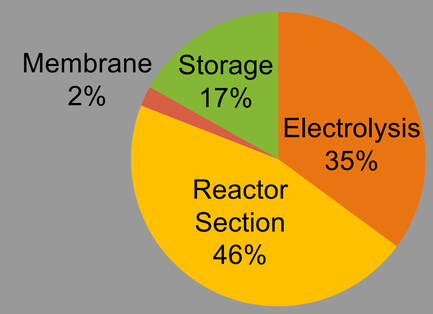
Operating Costs

- Yearly operating: $19.7 million.
- Sales price: $1.19/kg of NH_3
- Break-even: **$1.48/kg of NH_3**



SR = Sales Related Costs
CR = Capital Related Costs

Capital Costs



Modular Costs

Module Number	Installed Cost (Millions USD)
1	$ 11.4
2	$ 9.08
3	$ 7.97
4	$ 7.27
5	$ 6.76
Total	$ 42.4

Conclusions

- Carbon-free plant designed is currently not profitable
- Research ways to reduce reactor and electrolysis capital cost
- Electricity cost analysis needed