COLLEGE OF ENGINEERING

Chemical, Biological, and Environmental Engineering

INDUSTRIAL PRODUCTION OF AMMONIA FERTILIZER USING CYANOBACTERIA

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AICHE PROJECT GUIDELINES

- Proposed Plant should have a production capacity of 50 mtpd
- Plant should employ modular construction methods
- Plant should minimize greenhouse gas emissions

BACKGROUND

- Fertilizers are widely used in the world today, to increase the crop yield from any given area. The use of synthetic fertilizers increased heavily in the 1960's during the Green Revolution.
- One of the most common fertilizers used today is ammonia. Ammonia supplies crops with easily accessible nitrogen, which is an important component of chlorophyll. Plants use chlorophyll to photosynthesize, making nitrogen a key nutrient for plant growth. It is estimated that roughly half of the world's current population is sustained by ammonia fertilizers.
- Ammonia can be applied to crops either as pressurized anhydrous ammonia, which can be sprayed as a liquid, or as a water-soluble salt spread as solid pellets.
- Anhydrous ammonia is generally produced using the Haber-Bosch process. This process converts pure nitrogen gas and pure hydrogen gas into ammonia using a metal catalyst under high temperatures and pressures.
- Nitrogen gas is most often obtained from atmospheric air. Air is 79% nitrogen, and this nitrogen can be separated using varying techniques. The most popular separation technique is cryogenic distillation, but membranes or pressure swing adsorption are also sometimes used.
- Hydrogen is largely produced via steam methane reformation, which requires large amounts of natural gas. Alternatively, the electrolysis of water can be used to produce hydrogen gas but can often be energy intensive and expensive.

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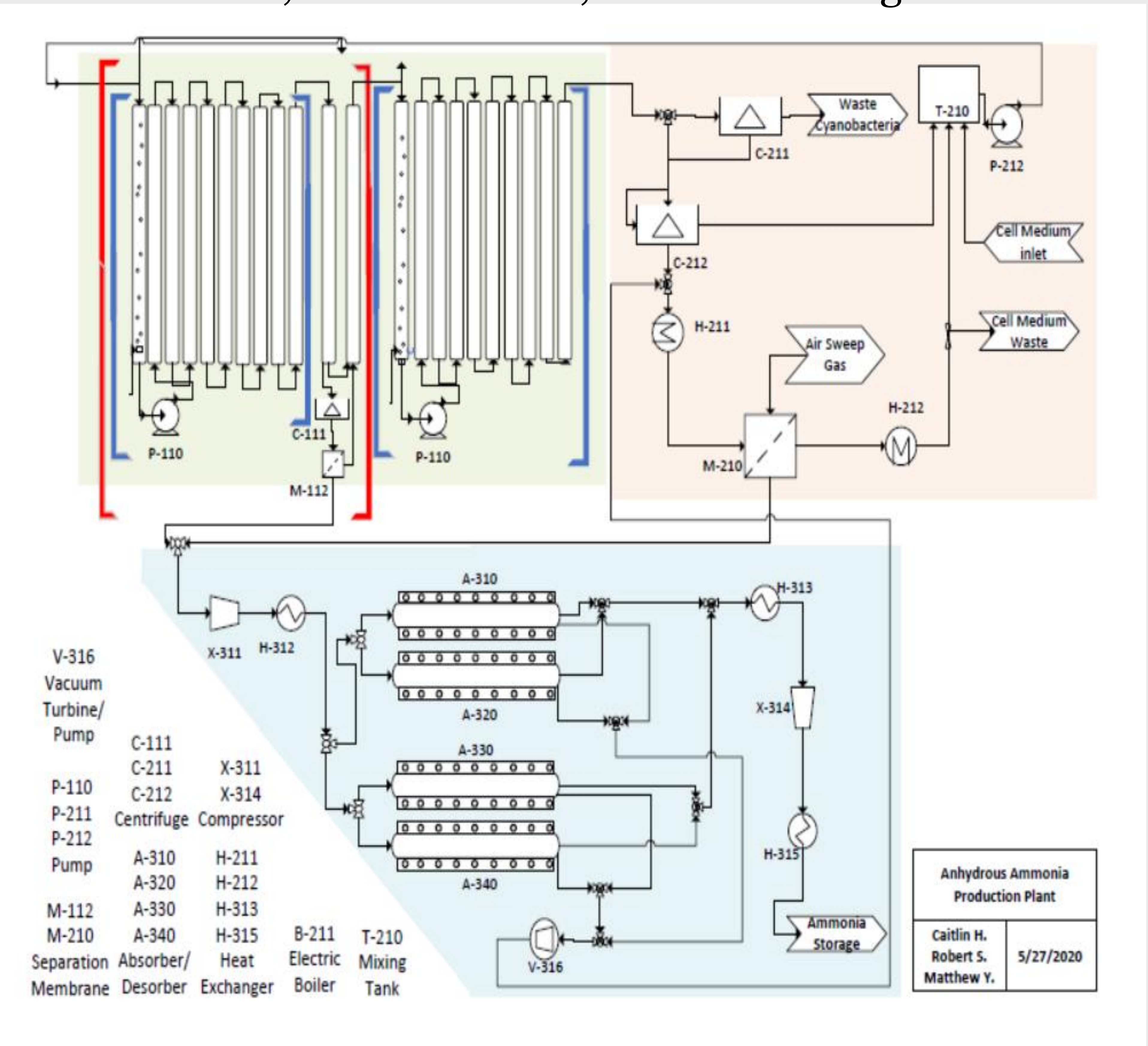

Figure 1: PFD of the ammonia production plant using cyanobacteria.

PROCESS DESCRIPTION

The ammonia production plant (Figure 1) features a circulating process, with cyanobacteria, medium, and air continually being recycled in the plant. Production of ammonia starts in the photobioreactor system (green), which is a series of connected clear vertical pipes that houses cyanobacteria in a culture medium. The aeration/pump repeating units are indicated by the blue brackets (Figure 1). Aeration occurs every 10 pipes, and then a pump sends the fluids through to the next aeration pipe. This unit is repeated 1504 times per centrifuge unit and 1504 times after the last centrifuge unit. The centrifuge repeating units are indicated by the red brackets and include the aeration/pump repeating units (Figure 1). Per module, the centrifuge repeating unit is repeated 18 times. As the cyanobacteria travel along the photobioreactor they produce ammonia, and at the end of the reactor they are sent to a membrane system for an initial separation.

The membrane system (orange) first separates out all of the cyanobacteria from the ammonia-laden culture medium, and then heats up the medium before running it over a membrane specific for ammonia extraction. Ammonia diffuses over the membrane into a strong flow of air, which is then diverted away to the separation system. The now ammonia free medium is cooled back down to culture temperature, reinoculated with the cyanobacteria, and is then recycled back into the photobioreactor system.

The ammonia and air then moves to the separation system (blue) where it is first compressed and then cooled. Then, the gaseous mixture encounters a set of 4 absorbers made up of a magnesium chloride and silica gel absorbent. Ammonia is selectively absorbed and the leftover air is recycled back into the membrane system. The section is designed so that one absorber is always desorbing while the others are either absorbing ammonia, heating to desorption conditions, or cooling back down for absorption. This way the process is still considered continuous. The anhydrous ammonia leaving the absorber is cooled and compressed to a liquid, and is then ready for storage and transportation.

FEASIBILITY & CONCLUSIONS

- As-designed capital costs were $461B, with manufacturing costs $156B/yr. Over 70% of costs were from energy infrastructure (wind turbines and battery storage).
- Net present value was -$350B, with an internal rate of return of -8%. Furthermore, the unit sales price was $9M/ton of ammonia, compared to a market price of $512/ton. The plant requires 31,000 3 MW wind turbines and 50,000 acres of land. This is not feasible, and the current design would be neither profitable nor marketable. To achieve marketability, unit sales price must be decreased by a factor of 18,000.
- An avenue to decrease costs is through further research and development of cyanobacteria that could allow for an increased cyanobacteria density and concentration.

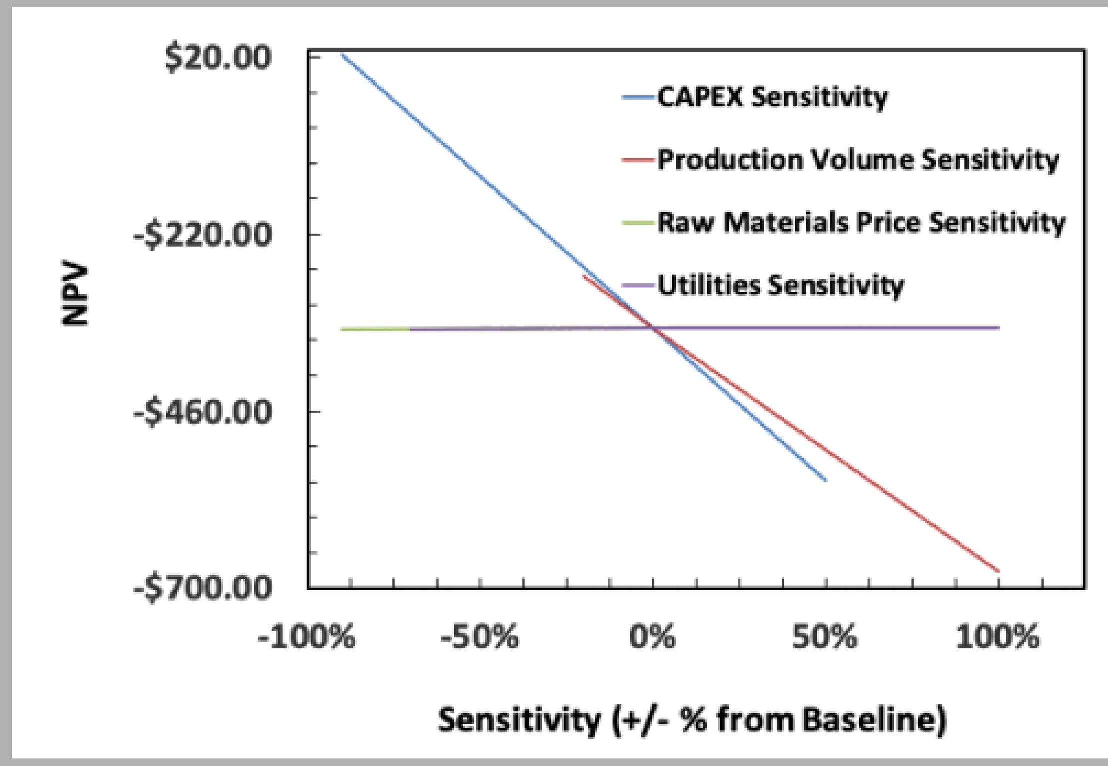

Figure 2: Cost sensitivity of Net Present Value vs. % changes in CAPEX, production volume, raw materials price, and utilities costs. CAPEX is the biggest cost driver.

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