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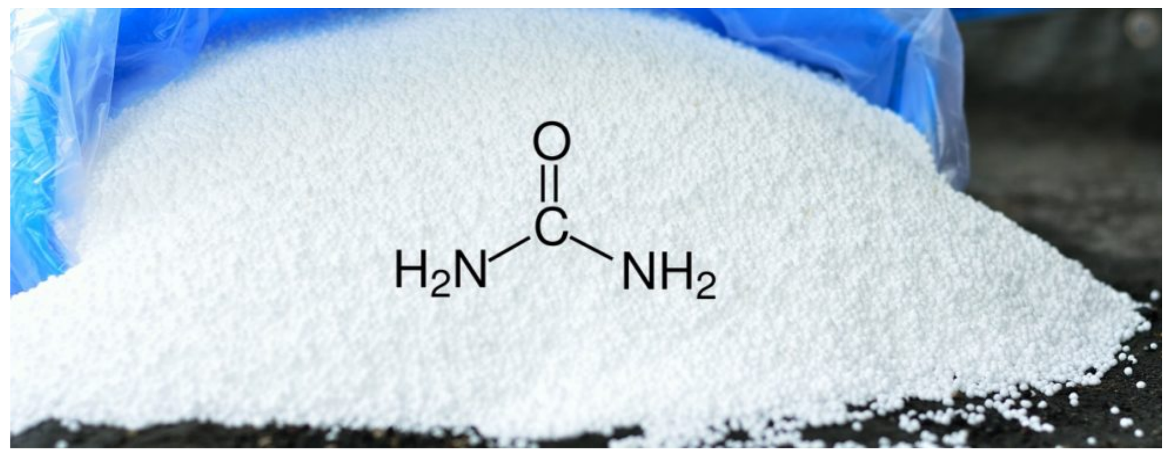
Urea Production Through Chemical Looping

Background

Urea is the world's most popular nitrogen-based fertilizer due to it being cost effective and having a high nitrogen concentration (up to 46%). The two main alternatives to urea are ammonium nitrate and liquid ammonium nitrate



Solid Urea

Urea has many other applications such as:

- A source of hydrogen, nitrogen, and clean water in which provides safe, sustainable, and long-term energy
- It is stable, and easy to transport and store

Urea is produced by ammonia (NH_3) and CO_2

- Ammonia is produced by hydrogen and nitrogen in the Haber-Bosch process
- Hydrogen, nitrogen, and CO_2 can be produced conventionally or through CLC

The scope of this project was to design a functioning urea production plant that utilizes CLC to produce the required reactants for the synthesis of ammonia (intermediate product) and urea (final product)

Problem

Design a urea plant using CLC and compare this to the conventional method of nitrogen, hydrogen, and CO_2 production

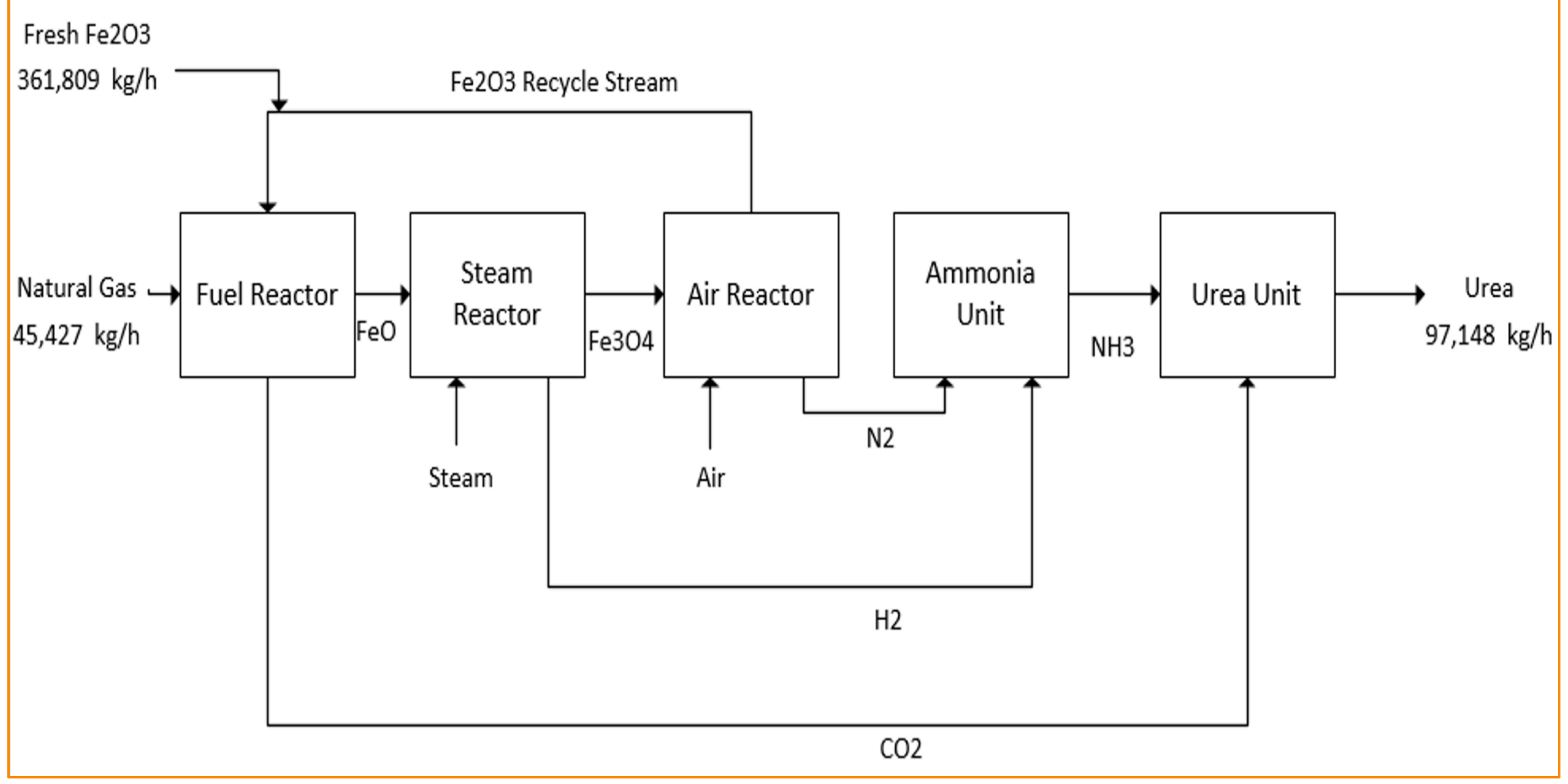
- Analysis focuses on a comparison of cost effectiveness and environmental effects between the two methods
- Choose most efficient oxygen carrier for CLC process
- Objective was to be able to produce 1.32 Mton/year (4 million kg/day) of urea given 330 working days

Chemical Looping Combustion (CLC)

CLC is an advanced technology for fossil fuel utilization and CO_2 capture

- Oxygen carrier particles are circulated among Air, Fuel and Steam fluidized bed reactors to prevent direct contact between air and fuel
- This method produces three pure streams consisting of nitrogen, hydrogen, and carbon dioxide
  - Considered as an attractive model due to its ability of splitting of reactions, resulting in pure streams
- CLC approach can play a role in energy conservation and emission reduction.
  - As reactive separation is enabled through oxygen carriers, CLC can simplify the conventional process by reducing the number of unit operations within the process

Process Design



Block Flow Diagram of Urea plant with CLC

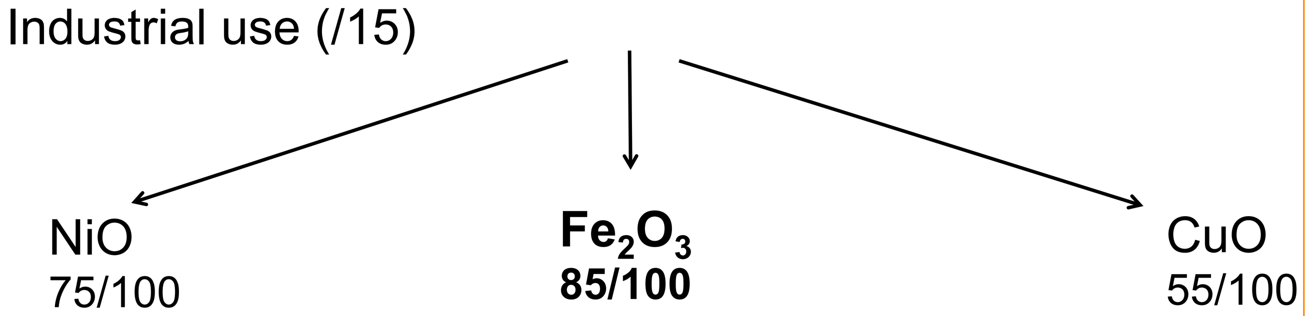
Comparison of Conventional and CLC Process

	CLC	Conventional
Cost Efficiency	Less equipment to operate	Three separate processes for CO_2, H_2, and N_2 production
Conditions	Pressure (20 bar) and temperatures (800 °C) are constant for each reactor	Pressure and temperatures for all equipment drastically differ
Compatibility	Allows for easy integration with other technology	Ensure technology wouldn't affect units in the process
Contamination	Low chance of catalyst poisoning	Unit needed for sulphur removal before ammonia synthesis.

Results and Analysis

Three CLC oxygen carriers graded in five categories (/100)

- Cost (/15), Kinetics (/40), Abundance (/15), Toxicity (/15), Industrial use (/15)



Three main plant sections

- N_2, H_2, and CO_2 synthesis via CLC
- Ammonia synthesis via the Haber-Bosch process
- Urea Synthesis via the Snamprogetti process

Urea Production

- Goal: Produce 4,000,000 kg/day of Urea
- Actual: 2,331,546 kg/day of Urea

Future Considerations

Further optimization on Process conditions

- Optimized conditions → Improved efficiency → Lower operating cost

Oxygen carrier testing

- Real life testing of the three carriers to improve process efficiency and economics

Conclusion

- A full urea production plant was constructed by performing:
  - Detailed research and analysis on each component of the plant.
  - Engineering tools were used to design each component.
  - All individual components were sized in accordance with industry standard.
  - All components were analyzed, and a dependent economic analysis was conducted.

References

- Sela, Guy. "Urea Fertilizers | Cropaia." Cropaia.Com, Cropaia, 29 Apr. 2019, https://cropaia.com/blog/urea-fertilizers/