Energy efficiency and CO_2 reduction potential in ammonia plants based on lean natural gas

RESEARCH | TECHNOLOGY | CATALYSTS

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Outline

- Energy efficient schemes for ammonia production
  - Low feed and fuel consumption
- Schemes for ammonia production based on lean natural gas
  - Balancing CO_2 and NH_3 for urea production
- Reducing CO_2 emission
- Process layout optimisation
- Case studies

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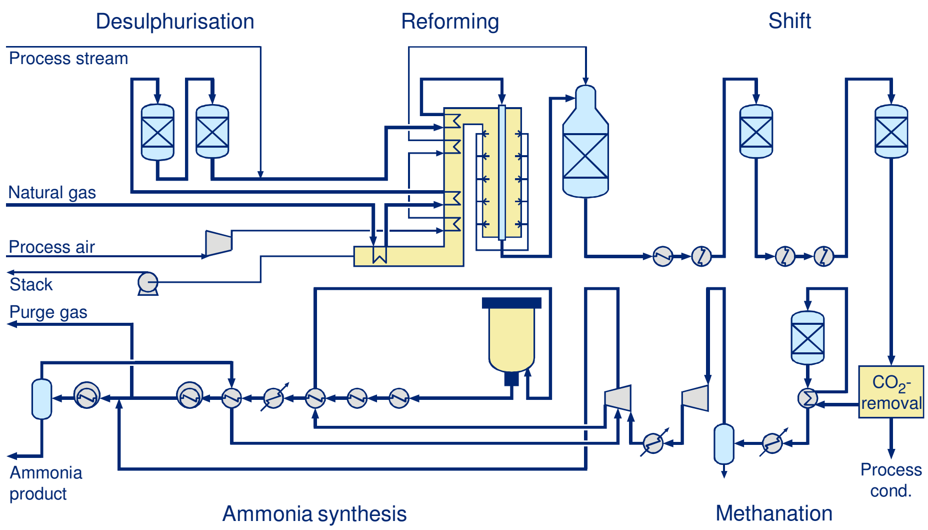
How is energy consumption optimised?

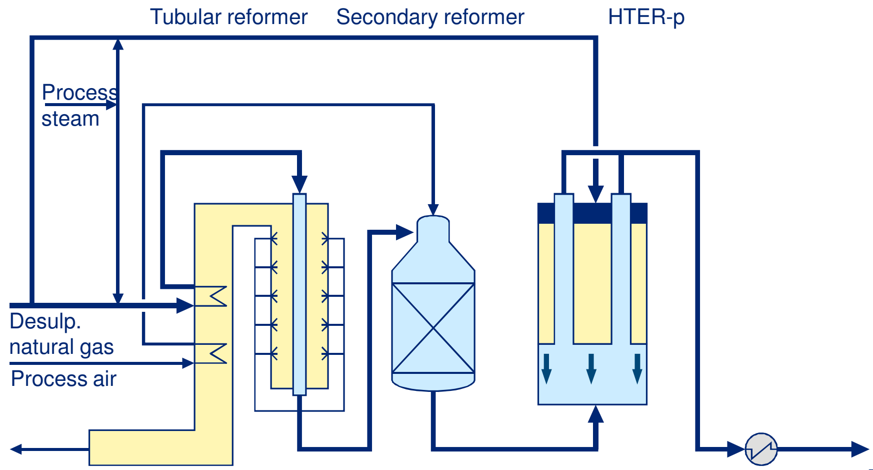


How is energy consumption optimised?

- Objectives? Requirements?
  - Lowest ISBL specific energy consumption
  - Best integration with entire complex
  - Maximise MP steam production and export
  - Save CAPEX

Reducing steam production

- HTER-p (Haldor Topsøe exchange reformer – parallel)



Balancing CO_2 and NH_3 for urea production using lean natural gas

- Cryogenic purification
- Excess synthesis gas production
- CDR (Carbon Dioxide Recovery) from flue gas
- Inclusion or exclusion of HRU (Hydrogen Recovery Unit)

Cryogenic purification

- Low exit temperature from primary and secondary reformer
- Excess process air to secondary reformer
- Cryogenic syntesis gas purification

- Feed flow adjusted to required CO_2 production
- Excess methane and synthesis gas is used as fuel in primary reformer
- Equipment size generally increases
  - Process air compressor

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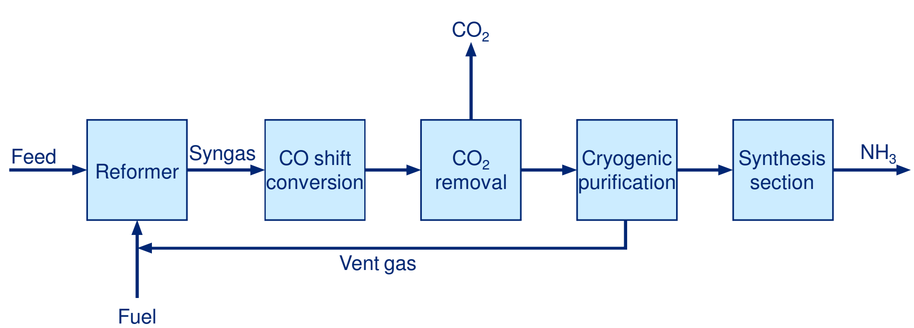
Cryogenic purification



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Excess synthesis gas production

- Feed flow increased to obtain required CO_2 production
- Excess synthesis gas used as fuel in primary reformer
- Flows are generally kept as low as possible
- Equipment size is kept as low as possible

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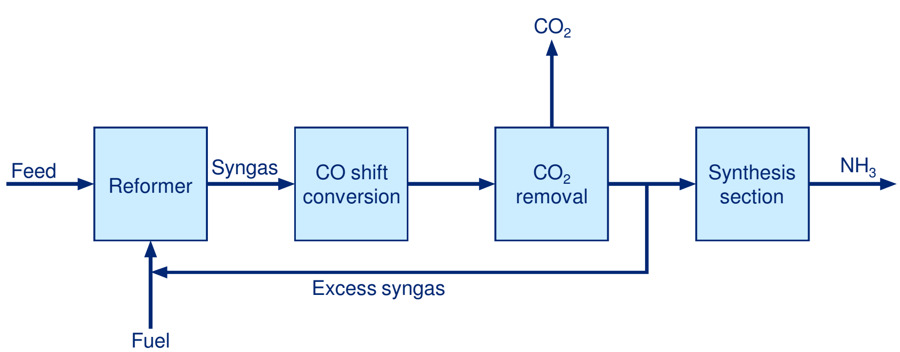
Excess synthesis gas production



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Carbon Dioxide Recovery (CDR)

- Scheme as for excess synthesis gas production
- CDR addition ensures sufficient CO_2 production

- Feed flow matches NH_3 requirement
- Equipment size kept minimal

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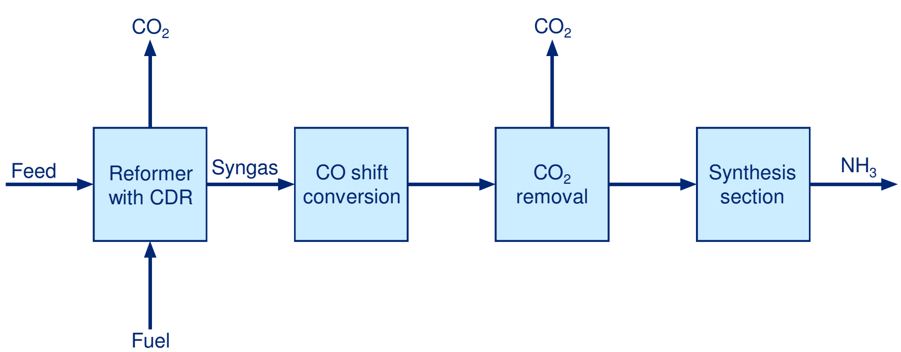
Carbon Dioxide Recovery (CDR)



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Hydrogen Recovery Unit (HRU)

- Reduces hydrogen loss from process
- Beneficial when NH_3 is limiting component in urea production
- Omission relevant when operating on lean natural gas
  - Enhanced off-gas flow resembles excess synthesis gas scheme
    - Feed flow as for excess synthesis gas scheme
    - Loop flow rates slightly higher
    - Reduction in number of equipment
    - Cost of HRU saved

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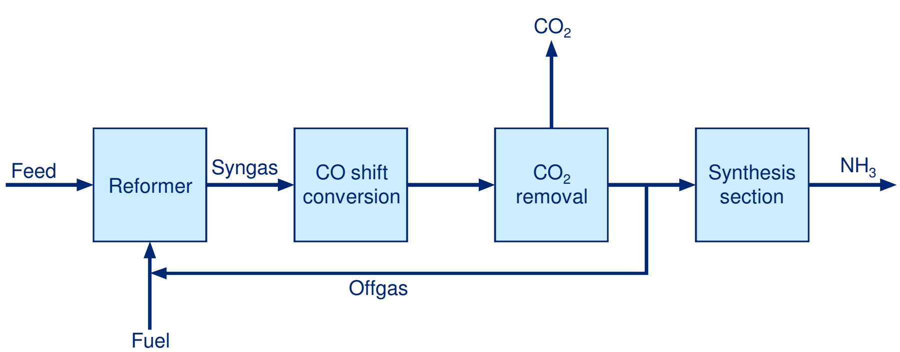
Hydrogen Recovery Unit (HRU)



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Steam system and carbon footprint

- Steam system considerations
  - Energy carrier
  - Pressure level
  - Production/export
- Carbon footprint considerations
  - HTER-p
    - Fuel consumption reduced
    - Primary reformer and steam piping size reduced
  - CDR

Case studies

- Basis:

Capacity of ammonia, MTPD	2,000
Natural gas composition, mole%	
CH_4	97.59
C_2H_6	2.10
C_3+	0.11
CO_2	0.10
N_2	0.10
Steam export as MP steam (44 kg/cm^2 g, 385°C)	
Only major compressors driven by steam turbines, the rest is motor driven	
All ammonia product to urea	

Base case

- Conventional layout
  - Primary and secondary reformer
  - Process air compressor driven by gas turbine
  - Two step shift section
  - CO_2 removal
  - Methanation
  - Loop with two converters in series

- Feed flow matches NH_3 requirement
  - CO_2 requirement not considered

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Base case

Natural gas consumption		
Feed, Gcal/MT NH_3	5.27	
Fuel, Gcal/MT NH_3	2.80	
Total natural gas consumption, Gcal/MT NH_3	8.07	
Production		
CO_2 production, MTPD	2,362	
MP steam export, ton/h	250	
Specific energy consumption		
Natural gas, Gcal/MT NH_3	8.07	
Electric power, Gcal/MT NH_3	0.30	
MP steam export, Gcal/MT NH_3	(2.27)	
Net consumption, Gcal/MT NH_3	6.10	

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Cryogenic purification case

- Primary reformer with lower outlet temperature
- Secondary reformer with excess air
- Process air compressor driven by gas turbine
- Two step shift section, CO_2 removal and methanation
- Driers
- Cryogenic purification
- Inert free loop
- Waste gas from cryogenic purification used as fuel

- Feed flow adjusted to meet CO_2 requirement

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Cryogenic purification case

Natural gas consumption		
Feed, Gcal/MT NH_3	6.34	▲
Fuel, Gcal/MT NH_3	1.64	▼
Total natural gas consumption, Gcal/MT NH_3	7.98	▼
Production		
CO_2 production, MTPD	2,606	
MP steam export, ton/h	193	
Specific energy consumption		
Natural gas, Gcal/MT NH_3	7.98	
Electric power, Gcal/MT NH_3	0.26	
MP steam export, Gcal/MT NH_3	(1.75)	
Net consumption, Gcal/MT NH_3	6.49	+0.39

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Excess synthesis gas case

- Conventional layout
  - Primary and secondary reformer
  - Process air compressor driven by gas turbine
  - Two step shift section
  - CO_2 removal
  - Methanation
  - Loop with two converters in series
- Feed flow adjusted to meet CO_2 requirement

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Excess synthesis gas case

Natural gas consumption		
Feed, Gcal/MT NH_3	5.81	▲
Fuel, Gcal/MT NH_3	2.54	▼
Total natural gas consumption, Gcal/MT NH_3	8.35	▲
Production		
CO_2 production, MTPD	2,606	
MP steam export, ton/h	275	
Specific energy consumption		
Natural gas, Gcal/MT NH_3	8.35	
Electric power, Gcal/MT NH_3	0.31	
MP steam export, Gcal/MT NH_3	(2.50)	
Net consumption, Gcal/MT NH_3	6.16	+0.06

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HTER-p with excess synthesis gas

- HTER-p in parallel to primary reformer
- Secondary reformer
- Process air compressor driven by gas turbine
- Two step shift section, CO_2 removal & methanation
- Loop with two converters in series

- Feed flow adjusted to meet CO_2 requirement

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HTER-p with excess synthesis gas

Natural gas consumption		
Feed, Gcal/MT NH_3	5.75	▲
Fuel, Gcal/MT NH_3	1.67	▼
Total natural gas consumption, Gcal/MT NH_3	7.42	▼
Production		
CO_2 production, MTPD	2,606	
MP steam export, ton/h	152	
Specific energy consumption		
Natural gas, Gcal/MT NH_3	7.42	
Electric power, Gcal/MT NH_3	0.31	
MP steam export, Gcal/MT NH_3	(1.38)	
Net consumption, Gcal/MT NH_3	6.35	+0.25

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CDR

- Conventional layout
  - Primary and secondary reformer
  - Process air compressor driven by gas turbine
  - Two step shift section
  - CO_2 removal
  - Methanation
  - Loop with two converters in series
- CDR unit included on flue gas
- Feed flow matches NH_3 requirement

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CDR

Natural gas consumption		
Feed, Gcal/MT NH_3	5.27	►
Fuel, Gcal/MT NH_3	2.80	►
Total natural gas consumption, Gcal/MT NH_3	8.07	►
Production		
CO_2 production, MTPD	2,362	
CO_2 captured, MTPD	244	
MP steam export, ton/h	237	▼
Specific energy consumption		
Natural gas, Gcal/MT NH_3	8.07	
Electric power, Gcal/MT NH_3	0.31	
MP steam export, Gcal/MT NH_3	(2.15)	
Net consumption, Gcal/MT NH_3	6.23	+0.13

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Scheme without HRU

- Conventional layout
  - Primary and secondary reformer
  - Process air compressor driven by gas turbine
  - Two step shift section
  - CO_2 removal
  - Methanation
  - Loop with two converters in series
- HRU omitted
- Feed flow adjusted to meet CO_2 requirement

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Scheme without HRU

Natural gas consumption		
Feed, Gcal/MT NH_3	5.81	▲
Fuel, Gcal/MT NH_3	2.50	▼
Total natural gas consumption, Gcal/MT NH_3	8.31	▲
Production		
CO_2 production, MTPD	2,606	
MP steam export, ton/h	265	
Specific energy consumption		
Natural gas, Gcal/MT NH_3	8.31	
Electric power, Gcal/MT NH_3	0.31	
MP steam export, Gcal/MT NH_3	(2.41)	
Net consumption, Gcal/MT NH_3	6.21	+0.11

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HTER-p with CDR

- HTER-p in parallel to primary reformer
- Secondary reformer
- Process air compressor driven by gas turbine
- Two step shift section, CO_2 removal and methanation
- Loop with two converters in series
- CDR unit included on flue gas
- Feed flow adjusted to meet NH_3 requirement

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HTER-p with CDR

Natural gas consumption		
Feed, Gcal/MT NH_3	5.32	▲
Fuel, Gcal/MT NH_3	1.96	▼
Total natural gas consumption, Gcal/MT NH_3	7.28	▲
Production		
CO_2 production, MTPD	2,371	
CO_2 captured, MTPD	235	
MP steam export, ton/h	123	
Specific energy consumption		
Natural gas, Gcal/MT NH_3	7.28	
Electric power, Gcal/MT NH_3	0.27	
MP steam export, Gcal/MT NH_3	(1.08)	
Net consumption, Gcal/MT NH_3	6.47	+0.37

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Conclusion

- Flexibility in design offers
  - Energy efficient schemes
  - Tailering to meet specific requirement, e.g. requirement for steam export
  - Balancing CO_2 production with NH_3 production
  - Significant reduction in CO_2 emission can be achieved

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