KBR Ammonia Technologies Improve Production Cost, Reliability, and Efficiency

Akhil Nahar, Vikram Singh – GPCA, Bahrain 2017
Agenda

– Introduction

– KBR Technologies Overview
  ▪ KRES™ TECHNOLOGY
  ▪ KBR’s TRUE COLD WALL ADD-ON AMMONIA CONVERTER

– Case Studies
  ▪ CASE STUDY FOR KRES™ TECHNOLOGY
  ▪ CASE STUDY FOR ADD-ON AMMONIA CONVERTER

– Conclusion
Present market context - need for reduction in NG consumption

- High price & reduced supply of natural gas
- New ammonia plants in countries with low cost natural gas and lower energy consumption

Existing plants have to stay competitive by:
- Expanding capacity – revamping of existing assets
- Improving energy efficiency
- Reducing dependence on natural gas
Revamp Strategy - Owner’s Dilemma

- Use of proven technology, update flow sheet
- Conventional methods sometimes don’t provide value for money
- Piece meal approach NOT providing full lifecycle cost benefit
- Revamp project goals (?)
  - Capacity increase: 20-25%
  - Steep energy saving > 0.5 G Cal/T
- What about customized solution for any type of flow-sheet?
  - Available for all existing technology plants
  - Proven and viable with documented commercial examples
  - Guaranteed ISBL plant performance
Do You Wish to..?

- Increase plant capacity
- Reduce plant energy consumption
- Reduce NG consumption of plant
- Reduce steam export from ammonia ISBL
- Move to alternative energy source e.g. coal available?
- Improve plant reliability
- Reduce Operating cost by using low cost energy alternative

✓ KBR HAS A SOLUTION !!!
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KBR
Reforming
Exchanger
System
Case History: Reforming capacity increase by KRES™

Reforming Exchanger upstream WHB: 30%+ more Syngas

Air + Steam → Mixed Feed → Primary Reformer → Secondary Reformer → To Heat Recovery

~ ~
KBR Reforming Exchanger

- Simple, compact, robust design
- Tubes packed with reforming catalyst
- Single tube sheet at the top
- Each tube free to expand
- Removable tube bundle
- Dual-layer refractory lined shell
- External water jacket
- Very reliable
KRES™ Heat Curve

- Heat used for reforming
- Heat used for steam generation

Temperature, °C
- Sec. Reformer Outlet
- HP Steam

Process Gas

Heat Curve Diagram
KRES™ Technology salient features

- Operating experience only with KBR
- KBR’s propriety and patented technology
- Debottleneck front end reforming capacity by 30%
- Improvement in Furnace efficiency
- Milder operating conditions for RG WHB
- No modification in steam system for revamped capacity
- Robust design
- KBR’s responsibility from design to commissioning
Benefits of KRES-based Revamps

- KRES increases reforming capacity by 25-30% or alternatively for same capacity, reduces the usage of expensive natural gas
- Expensive furnace modifications avoided
- Better use of high grade heat
- Reduces overall furnace emissions
- Parallel installation reduces pressure drop
- KRES can be installed while plant is in operation and tie-ins completed in short turnaround
- Reduces severity/constraints in waste heat boiler
- Lost steam production can be replaced using cheaper, alternative energy sources or by other efficiency improvements
<table>
<thead>
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<th>Remark</th>
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</tbody>
</table>
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   KRES™ TECHNOLOGY
   KBR’s TRUE COLD WALL ADD-ON AMMONIA CONVERTER

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   CASE STUDY FOR KRES™ TECHNOLOGY
   CASE STUDY FOR ADD-ON AMMONIA CONVERTER

– Conclusion
TRUE Cold Wall Add-on Converter

- Added in series to boost conversion
- Proven vintage MWK design, cold sweep gas, like “Slim-Jim” of 1960s
- Cold wall 150+ still in use, 30-50 yrs
- Patented annulus flow feature
- Revamp for capacity gain, energy saving or reliability
- Replace hot wall converters
- Low cost/multiple vendors
- Cold wall (vs hot wall) provides higher reliability
- Catalyst use/conversion: Overall life cycle better due to ability to run the bed hotter
COLD WALL ADD-ON CONVERTER BENEFITS

• Higher optimum bed inlet T for add-on converter due to NH$_3$%, cold wall technology better fit, reliable, cost effective

• Bed inlet temperature control, startup connection- existing heater

• Cooler shell allows multiwall shell, more vendor options, faster delivery, no startup restrictions
Typical Flowsheet with Add-On Converter

LOW TEMP GAS SUITABLE AS SWEEP GAS
<table>
<thead>
<tr>
<th>Customer</th>
<th>Capacity NH3</th>
<th>Commissioned</th>
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<tbody>
<tr>
<td>CFCL Ammonia I</td>
<td>1800 MTPD</td>
<td>2016</td>
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<tr>
<td>CFCL Ammonia II</td>
<td>1750 MTPD</td>
<td>2017</td>
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<tr>
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<td>In progress</td>
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<tr>
<td>* Allied Chemicals (PCS Nitrogen)</td>
<td>1000 STPD</td>
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</tr>
<tr>
<td>* Agrico Chemicals (Mosaic)</td>
<td>1000 STPD</td>
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<tr>
<td>* Comm/Solvents</td>
<td>970 STPD</td>
<td>1967</td>
</tr>
<tr>
<td>* Allied Chemicals</td>
<td>1000 STPD</td>
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<tr>
<td>* Union Explosives</td>
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Case study: KRES™ Technology

Facility Description
- Plant location - Lima, Ohio, USA
- Constructed in 1971
- Ammonia technology/EPC - Bechtel
- Reformer design - Foster Wheeler
- Original capacity - 1360 MTPD (1500 STPD)
- Capacity prior to revamp - 1678 MTPD (1850 STPD)
- Target capacity of revamp - 1955 MTPD (2150 STPD)
Case study for KRES™ Technology

Why KRES (KBR Reforming Exchanger System) for Revamps?

- Minimal modification for primary reformer
- Minimal impact on reformed gas waste heat boiler
- Previous successful installations:
  - Methanex, Canada, 1994
  - Liaohe, China, 2003
  - Chambal Fertilizer and Chemicals, India, 2009
  - Lima, Ohio, USA, 2015
- KRES Island supported by KBR throughout all phases, from conceptual study to startup
Case study for KRES™ Technology

Study Phase

- PCS evaluated options & selected KRES for study phase
- Study began in May 2012
- Confirmed the benefit of KRES technology in this revamp
- Preliminary constructability study & review
- Preliminary equipment arrangement including new secondary reformer
Engineering Phase
- Began in August 2012
- Process simulations finalized
- Confirmed equipment and piping arrangement
- P&IDs completed
- HAZOP performed
- Equipment requisition produced for secondary reformer and transfer lines
- Structural design completed
- Constructability review completed
- Model review completed
- Coordination of three engineering contractors

Case study for KRES™ Technology
Case study for KRES™ Technology

Construction

- **2014**
  - Installed foundations for new Secondary Reformer and KRES Exchanger - August
  - Erected new Secondary Reformer and KRES Exchanger in the operating plant - December

- **2015**
  - Install castable refractory and dome brick in the new Secondary Reformer – July/August
  - Loaded KRES catalyst - July
  - Demolished old Secondary Reformer, transfer piping, and process air line - August*
  - Install new transfer line, process air line, mixed feed line, and primary steam coil piping - August*
  - Loaded Secondary Reformer catalyst – August*
  - Installed KRES bundle - August*

(*) 6 week plant outage
Case study for KRES™ Technology

Construction Benefits

- KBR Construction and Installation Plan
- KBR Construction Quality Checklist
- KBR onsite personnel to support construction contractors
- Significant efforts to plan all crane lifts resulted in zero incidents or injuries for extremely complex lifts
- Constructability and 3D model reviews aided construction by designing in lift-points
Case study for KRES™ Technology
Commissioning, Start-up, Performance Test

♦ Commissioning and start-up began in October 2015
♦ Daily operations meetings
♦ Punch lists used
♦ KRES start-up was smooth and trouble-free
♦ Performance test was performed in March 2016
♦ No performance issues - all guarantees were met
♦ Performance test run – 2090 MTPD (2300 STPD) ammonia capacity not limited by KRES
♦ Quality of reformed syngas on spec, CH4 slip and steam import within limits
Case Study: Add-on Converter revamp at CFCL

<table>
<thead>
<tr>
<th></th>
<th>Before revamp</th>
<th>After revamp</th>
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<tbody>
<tr>
<td>Ammonia Production</td>
<td>MTPD</td>
<td>1604</td>
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<tr>
<td>Synthesis Pressure</td>
<td>Kg/cm²g</td>
<td>208</td>
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<tr>
<td>NH₃ exit converter</td>
<td>mol%</td>
<td>19.6</td>
</tr>
</tbody>
</table>

- Non-KBR Technology plant
- High per pass conversion despite ~ 30 Kg/cm²g lower loop pressure
- No change in catalyst for existing converter
- Power for Syn and Refrigeration compressor reduced
- Steam requirements for turbines reduced
<table>
<thead>
<tr>
<th>Client</th>
<th>Location</th>
<th>Type</th>
<th>Description</th>
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<td>Capacity &amp; Energy</td>
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<td>Australia</td>
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<td>Converter Basket</td>
<td>Ongoing</td>
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## Recent revamp projects

<table>
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<tr>
<th>Client</th>
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<td>NFL</td>
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  ▪ KBR’s HIGH PRESSURE REFORMING
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– Conclusion
Conclusion

- There’s often a strong business case for revamp
  - Lack of economy of scale
  - High operating costs
  - Aging equipment / older technology / unreliable equipment due to increased load

- KBR is a pioneer in revamping existing ammonia plants for over 50 years

- KBR technology revamps improve reliability and operability

- Results in higher returns to plant owners

- KBR has solution for any client requirement
THANK YOU