INTEGRATED SOLUTIONS FOR AMMONIA/UREA PLANTS

Phil Millette
11-June-2019

Americas HUG
Integrated Solutions for Ammonia / Urea
Agenda

• Ammonia / Urea Market Overview

• Honeywell in Ammonia / Urea
  – Presence, value

• Integrated Solutions
  – KPI’s/ MES
  – APC
  – OTS – Training Simulation / competency management
  – Process Safety

• Example projects

• Summary
Ammonia Market outlook

- Capacity additions in areas with low cost natural gas and higher gas availability
- Coal-fed ammonia in China is reducing – on pollution concerns
- May move to surplus capacity during the forecast period but growth firms up markets only after 2021
  - Lower operating rates: Efficiencies will be key to success.
- Capacity growth 2011-2016 was 27MMT/Yr – 3.1% annual rate
- Capacity additions from 2018 mostly from USA, EE – NOT from China
- Global Ammonia trade is relatively low % of total volume.
- Operating Rates expected to go down due to capacity additions

Main areas of capacity additions:
Most are associated with downstream Urea

World Increase in Ammonia Capacity 2016-2021
Thousands Metric Tonnes/Yr

<table>
<thead>
<tr>
<th>Region</th>
<th>Capacity (MMT/Yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern Europe</td>
<td>9536</td>
</tr>
<tr>
<td>USA</td>
<td>5892</td>
</tr>
<tr>
<td>Africa</td>
<td>3435</td>
</tr>
<tr>
<td>Middle East</td>
<td>3125</td>
</tr>
<tr>
<td>South West Asia</td>
<td>2492</td>
</tr>
<tr>
<td>South East Asia</td>
<td>1820</td>
</tr>
<tr>
<td>China</td>
<td>1580</td>
</tr>
<tr>
<td>Central &amp; South America</td>
<td>935</td>
</tr>
<tr>
<td>Central Europe</td>
<td>480</td>
</tr>
<tr>
<td>Mexico</td>
<td>107</td>
</tr>
<tr>
<td>Canada</td>
<td>106</td>
</tr>
<tr>
<td>WE</td>
<td>75</td>
</tr>
<tr>
<td>Auz/NZ</td>
<td>0</td>
</tr>
<tr>
<td>Japan</td>
<td>0</td>
</tr>
<tr>
<td>World</td>
<td>29583</td>
</tr>
</tbody>
</table>

Global Capacity:
- 2011 165MMT/Yr
- 2016 192MMT/Yr
- 2021 221MMT/Yr
Urea Market Outlook

- Capacity additions in areas with low cost natural gas and higher gas availability
- Capacity growth 2011-2016 was 19.5MMT/Yr – 3.7% annual rate
- Capacity additions from 2018 mostly from EE, SWA, ME – NOT from China
- Global Urea trade is around 28% of whole market.
- Operating Rates expected to go down due to capacity additions

Global Capacity:
- 2011: 87MMT/Yr
- 2016: 107MMT/Yr
- 2021: 128MMT/Yr

Main areas of capacity additions:

<table>
<thead>
<tr>
<th>Region</th>
<th>Capacity Increase (MMT/Yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern Europe</td>
<td>4,183</td>
</tr>
<tr>
<td>Southwest Asia</td>
<td>3,878</td>
</tr>
<tr>
<td>Middle East</td>
<td>3,240</td>
</tr>
<tr>
<td>Africa</td>
<td>2,765</td>
</tr>
<tr>
<td>United States</td>
<td>2,643</td>
</tr>
<tr>
<td>China</td>
<td>2,490</td>
</tr>
<tr>
<td>Central and South America</td>
<td>909</td>
</tr>
<tr>
<td>Southeast Asia</td>
<td>887</td>
</tr>
<tr>
<td>Mexico</td>
<td>413</td>
</tr>
<tr>
<td>Western Europe</td>
<td>118</td>
</tr>
<tr>
<td>Canada</td>
<td>21</td>
</tr>
<tr>
<td>Central Europe</td>
<td>0</td>
</tr>
<tr>
<td>Oceania</td>
<td>0</td>
</tr>
<tr>
<td>Japan</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>21,547</strong></td>
</tr>
</tbody>
</table>

Source: Data are compiled from the respective sections of this report. © 2016 IHS
Ammonia / Urea industry trends

• Safety
  • Continue to increased focus on safety and security - Plant, Process & Personnel Safety

• Reliability
  • Managing aging infrastructure and retiring workforce in OECD
  • Getting max uptime - Managing new world-scale plant assets with less skilled resources in emerging regions
  • Keeping close track of major rotating machinery health and performance

• Efficiency
  • Operating under strain of generally lower operating rates for next several years
    • Out-compete peers to capture max value from fixed cost
  • Low cost feedstock areas still advantaged – Urea trade is > 25% of world consumption
  • Reducing startup and operating costs

• Sustainability
  • Increased Energy Efficiency to reduce cost and emissions
  • Increasingly stringent environmental requirements
Honeywell in Fertilizers

Leading player in automation for fertilizers, especially ammonia and urea

Partner with global industry leaders

Full portfolio – from field to supply chain

Honeywell controls ~ just under 30% of ammonia production

Leader in integrated DCS, safety and F&G

Leader in Ammonia/ Urea advanced apps e.g. Profit Suite; OTS; MES; Alarm Mgt
Honeywell Customers for Fertilizers

Abu Qir Fertilizers
Acron
Advansix
Agrrium Inc
Agropolichim
Azot Cherkassy
Azot Cherepovets
Azot Grodno
Balance Agri-Nutrients
BASF
Borealis
CF Industries
Chambal Fertilizers
Chittagong Urea Fertilizer Factory Ltd (CUFL)
Duslo as
Engro Chemical Pakistan Ltd

FACT
Fertiberia SA
Fertil - Ruwais
Fertinitro
GPIC
Grupa Azoty - ZCP Police
Gujarat Narmada
HURL (India)
IFFCO
Incitec
IndoGulf
Kemira SA/NV
Koch Nitrogen
Liaohe Chem Fertilizer
Madras Fertilizers Ltd
Metafrax
National Fertilizers Ltd
Nevinnomissky Azot

OCI Agro
PCS Nitrogen Trinidad Ltd
Petrochina Nigxia
PPZ Odessa
PT Kaltim
PT Pusri
QAFCO
Rashtriya (RCF)
Sinopec
SOCAR
Tata Chemicals
Terra Industries
Togliatti Azot (Toaz)
Uzbekneftegas
Yara International
Yunnan Yuntianhua
And others…
Experience with all licensed Ammonia/ Urea Processes

[Diagram of various companies: Casale, Bechtel, Jacobs, Kemira, Haldor-Topsoe, Exxon Chem, GIAP, Saipem, KBR, Snamprogetti, TKIS – Uhde, Chemico, Toyo, Tecnimont – Stamicarbon]
Honeywell’s Summary Value proposition in Fertilizer plants

<table>
<thead>
<tr>
<th>Improvement</th>
<th>Benefit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Institutionalize best practices</td>
<td>Improve product consistency</td>
<td></td>
</tr>
<tr>
<td>Support for continuous Improvement</td>
<td>Reduce Cost of Production</td>
<td>Improve capacity by 1-5%</td>
</tr>
<tr>
<td></td>
<td>Improve yields of most valuable products</td>
<td>Improve yields 1-3%</td>
</tr>
<tr>
<td></td>
<td>Reduce energy consumption</td>
<td>Reduce energy consumption 1-3%</td>
</tr>
<tr>
<td></td>
<td>Quality variability reduction of 50%</td>
<td>Quality variability reduction of 50%</td>
</tr>
<tr>
<td>Improved alignment with business</td>
<td>Reduce raw material costs</td>
<td>Improve reliability, availability 2-8%</td>
</tr>
<tr>
<td></td>
<td>Reduction in inventory</td>
<td></td>
</tr>
<tr>
<td>Increase production by pushing closer to multiple constraints</td>
<td>Increase available capacity</td>
<td>Reduce start up costs</td>
</tr>
<tr>
<td>Reduce time to achieve full production after unit start-up</td>
<td>Improved reliability and available capacity</td>
<td>• Faster startup by 2-3 days per unit</td>
</tr>
</tbody>
</table>
## Honeywell’s Summary Value proposition in Fertilizer plants

### Qualitative Benefits

<table>
<thead>
<tr>
<th>Improvement</th>
<th>Benefit</th>
</tr>
</thead>
</table>
| Make more timely, accurate information available | Spend less time collecting and scrubbing data, more time using the information  
Free operating team to focus on business not ‘fire fighting’ |
| Use supported applications and tools             | Reduce cost of compliance and ownership (integrated tools)  
Reduced maintenance cost |
| Increased capacity when market demand is there   | Ability to meet more market opportunities with less impact on overall production |
| Improved reliability may enable the plant to run longer between Shutdowns | Reduction in operating costs and avoidance of unplanned shutdowns |
| Institutionalize best practices                  | Prepare for loss of experienced workers through retirement and be able to quickly and effectively train new employees for new construction in developing regions |
| Support for innovation                           | Reduce time to absorb new technology into normal operation. |
Typical Ammonia KPI’s

- **Overall Plant**
  - Ammonia production, Specific Energy Consumption CO2 production, Natural Gas consumption, Steam exports and imports, Water Quality, Plant onstream factor

- **Reforming**

- **Purifier**
  - H/N Ratio, expander pressure drop & work extracted

- **Ammonia Converter**
  - Catalyst activity, conversion, bed temperature profile, internal flows, inerts in synthesis loop, cold and warm ammonia product flows

- **Chiller**
  - Heat duties, process temperatures and pressures

- **Compressors**
  - Polytropic head and efficiencies, speed, power, compression ratio, steam turbine efficiencies, steam flow rates
Ammonia / Urea plant MES – key functions

• Production Balancing – daily cycle
  – Electrical energy balance
    ▪ Amperage data, Balance across sections & feeders, reports, production costing
  – Natural Gas balance
    ▪ Find missing or inaccurate measurements, Provide data for emissions, reports & production costing
  – Plant balances
    ▪ Verify production & consumption values, stock/ inventory levels, Capture any stock discrepancy

• Emission Management
  – Using Lab Data as well as Analyzers / GC’s, Valve characteristic check – Cv vs Opening, Furnace calculations – SOx, CO2, Chemical emissions
  – Aggregation & Reporting

• Production Loss Analysis
  – Capture loss events, quantify by rate loss or downtime
  – Assign causality, Reporting

• Quality Management
  – LIMS: Scheduling, Sampling, Costing, lab instruments, certification, customs documents

• KPI / Performance Mgmt – examples per previous slide

• Production costing – Cascaded costing model
Ammonia Production APC Case

• Main benefits at Steam Reformer
  – Fuel (NG) savings
  – Steam savings
  – APC maintains stable Process gas temperature at Reformer (stage) outlet
    ▪ APC reduces its variation (by ~ 25 %)
    ▪ That enables energy saving – effective Fuel Gas consumption reduction

• Secondary benefits in increased ammonia yield from Synthesis
  – Stabilization of cooler outlet temperature
  – Reduction of ammonia return into synthesis reactor
  – APC business case identified 5 extra days of NH3 production per year (~ 1.5 % extra yield)
Urea Production APC Case

• Control opportunities
  – Lot of interactions and lot of recycle streams
  – Improve NH3/CO2 ratio in carbonation reactor inlet
  – Improve CO2 compressor suction pressure stability (variation in recycles)
  – Stabilized reactor leads to stabilization in downstream sections

• Energy saving opportunities
  – HP steam for CO2 Compressor
  – Optimizing NH3/CO2 improves conversion and reduces steam consumption downstream
  – Reducing water recycle, stabilizing conductivity reduces steam consumption
Ammonia – OTS - Operator Training simulators & Competency mgmt

• Honeywell has done more than 25 Ammonia/ Urea OTS
• Honeywell’s UniSim Operations Suite provides a dynamic simulation solution
  – train and develop operators on procedures and systems that are safe, tested and
    optimized prior to being exposed to the real plant.
• High fidelity model of an Ammonia and Urea complex that is unmatched in the
  industry
  – Includes fault models that represent suitable training scenarios for new fertilizer
    operators.
  – For example, common training scenarios include
    ▪ loss of the ammonia compressor,
    ▪ loss of reformer fuel gas pressure,
    ▪ unit start up /shutdown
• Assess an individual operator’s readiness by testing against tailored exercises
  representing real process upsets.
  – Operators practice responses to abnormal situations such as a methane breakthrough
    from the methanator into the ammonia converter.
  – Assessment gives process teams the confidence that your procedures have been
    validated against the dynamic behavior of your process and controls.
Ammonia Process Safety work

- Real life example
- HAZOP review after near miss
- Process Safety Management
  - LOPA and SF review
Ammonia Process Safety – recorded events globally

• Real life examples

• **Underscore the importance** of due care and attention to Process Safety design

**BFW Preheater Exchanger Leak**
- Wetting incident of the low temperature shift (LTS) converter catalyst led to a major outage.
- The root cause was BFW leaking through tubes in its upstream gas cooler. Drying the catalyst slowly with nitrogen fully restored its activity.

**Process Air Compressor Damage**
- Steam back-flow in the compressor discharge header during plant start-up caused the compressor to reverse rotation, which damaged the high-pressure-stage rotor. Although other factors contributed to this event, a lack of communication with maintenance and an inadequate lockout and tag-out (LOTO) system were the main causes of this incident. The actions taken were:
  - Air compressor discharge actuator replaced with a resized actuator.

**Syngas Compressor Failure**
- Several factors contributed to the compressor failure:
  - A rapid change in speed
  - A slow speed change in the critical speed zone
  - Gas passing through synloop shutoff valves and check-valve
  - Rapid depressuring of the synloop
  - Reversal of the compressor’s rotation
- Syngas compressor labyrinths were damaged and were replaced. Thrust bearings in the HP case were also replaced.
Success in the industry – Casale for Metafrax

- Honeywell is working with Casale to deliver a range of modular process equipment, control, safety and information solutions and competency management systems including:
  - **Experion® Process Knowledge System** with nine **Experion® Orion** workstations
  - **Safety Manager**
  - **Uniformalce® Process History Database** for the collection, storage and analysis of process data
  - **Field Device Manager** for simplification of maintenance tasks and complete device configuration
  - **UniSim® Operator Training Simulator** for skills training specific to melamine production and
  - **Honeywell UOP Pressure Swing Adsorption** (PSA) unit for hydrogen recovery and purification
Successes of Integrated solutions in Ammonia / Urea processes

- Fertinitro trained 80 operators and eliminated operational errors with Honeywell OTS – and huge success applying APC
- QAFCO benefits from wide ranging solution set from control, to APC to MES
  - Largest single site ammonia / urea plant in the world
- HULR India – implementing Experion & Safety Manager at 3 sites, via Technip
- Fertil – large multi train ammonia / urea site
- Agrium – with APC and OTS
- Tata Chemicals with APC
- Rashtriya Chemicals and Fertilizers – APC on Haldor Topsoe unit
- Kribhco migrates entire complex - 3 boilers, 2 steam generators, two ammonia plants, 4 urea plants and ammonia extension project from legacy competitor system to Experion & Safety Manager
- Phosagro Cherepovets success with APC
- BASF Ammonia APC
- EuroChem OTS
Summary

• Handling full scope of automation, control, safety, people skills, plant & personnel safety and optimization is most efficient way to achieve performance improvement

• Domain knowledge of key processes – experience in simulation and optimization are key.

• Seamless automation from field devices to MES to IIoT implementation brings maximum benefits.

• Honeywell has been delivering Ammonia/ Urea solutions for many years – leading the market
  – Controlling just under 30% of Ammonia global capacity over 120+ sites.
THANK YOU

REVEAL YOUR BEST