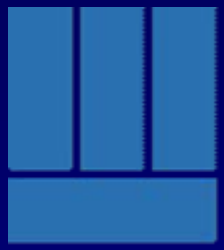
Reinhold Environmental Ltd.

2007 NOx Round Table & Expo Presentation

February 5-6, 2007 in Cincinnati, OH



WAHLCO, INC.®

U_2A^{TM} Technology

2007 NOx / PCUG

February 6, 2007

U_2A^{TM} System

- U_2A^{TM} (urea to ammonia): Reducing risks associated with ammonia handling:
  - No shipping, handling, transfer or storage of ammonia
  - Urea – a very safe material –produces ammonia at the point of use by a simple and easy to control process
  - Usually easier and less expensive to gain and maintain urea permits than for anhydrous ammonia
  - (U.S. patents 6,077,491, 6,322,762, 6,436,359 and
  - 6,506,350; European and Asian patents issued or pending)

Ammonia Effects

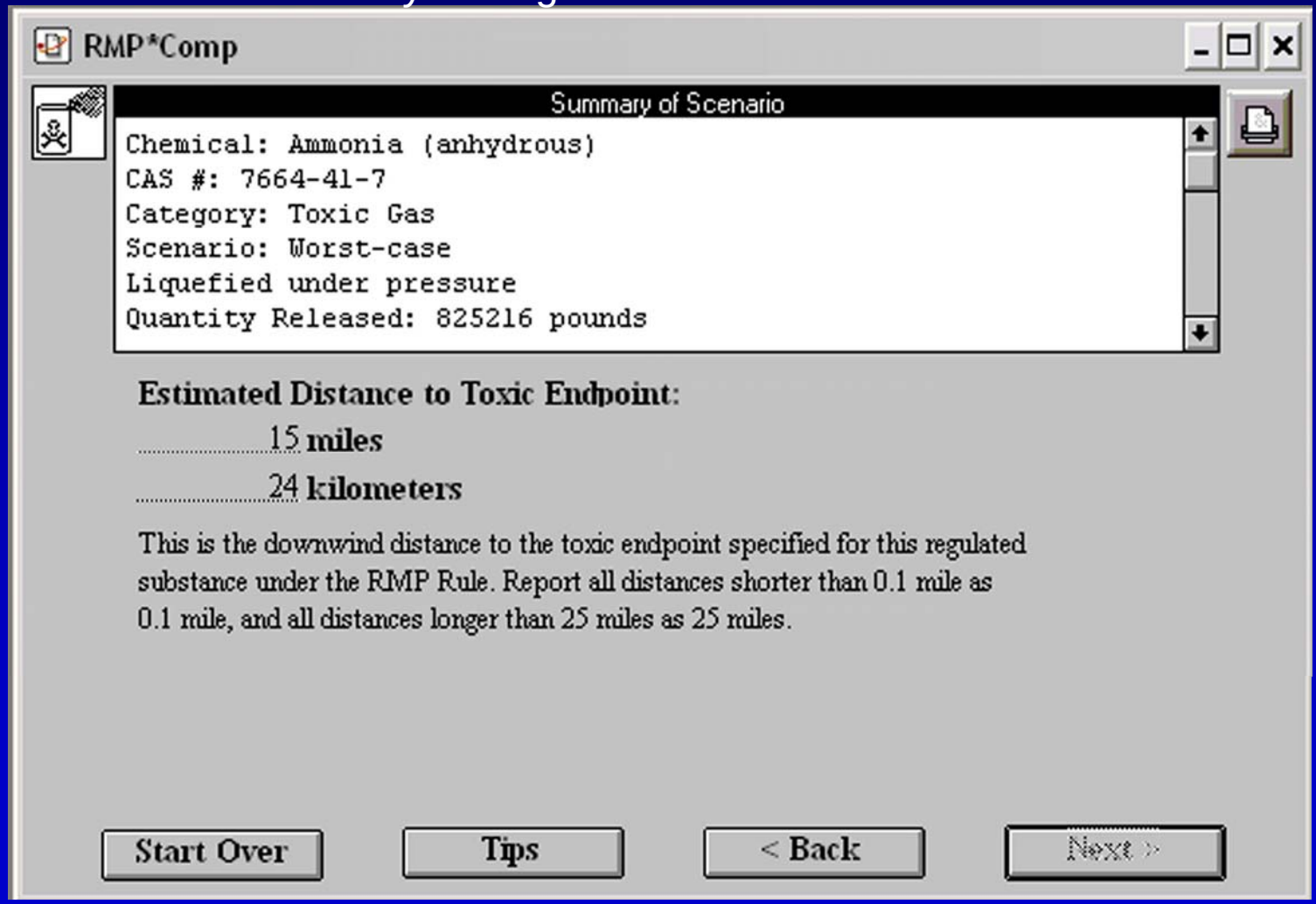
Effect	Ammonia ppm
Least perceptible odor	5 ppm
Readily detectable odor	20-50 ppm
No discomfort or impairment of health for prolonged exposure	50-100 ppm
General discomfort and eye-tearing; No lasting effect on short exposure	150-200 ppm
Severe irritation of eyes, ears, nose and throat; No lasting effect on short exposure	400-700 ppm
Coughing, bronchial spasms	1,700 ppm
Dangerous, less than ½ hour exposure may be fatal	2000-3000 ppm
Serious edema, strangulation, asphyxia, rapidly fatal	5000-10,000 ppm
Immediately fatal	>10,000 ppm

Modeling NH3 Release

- EPA RMA Comp Program
- Model several different toxic liquids and gasses
- Predicts toxic radius
- Program available from EPA.gov website

EPA RMP Comp

14 Day Storage for 4 units each 612 lb/hr

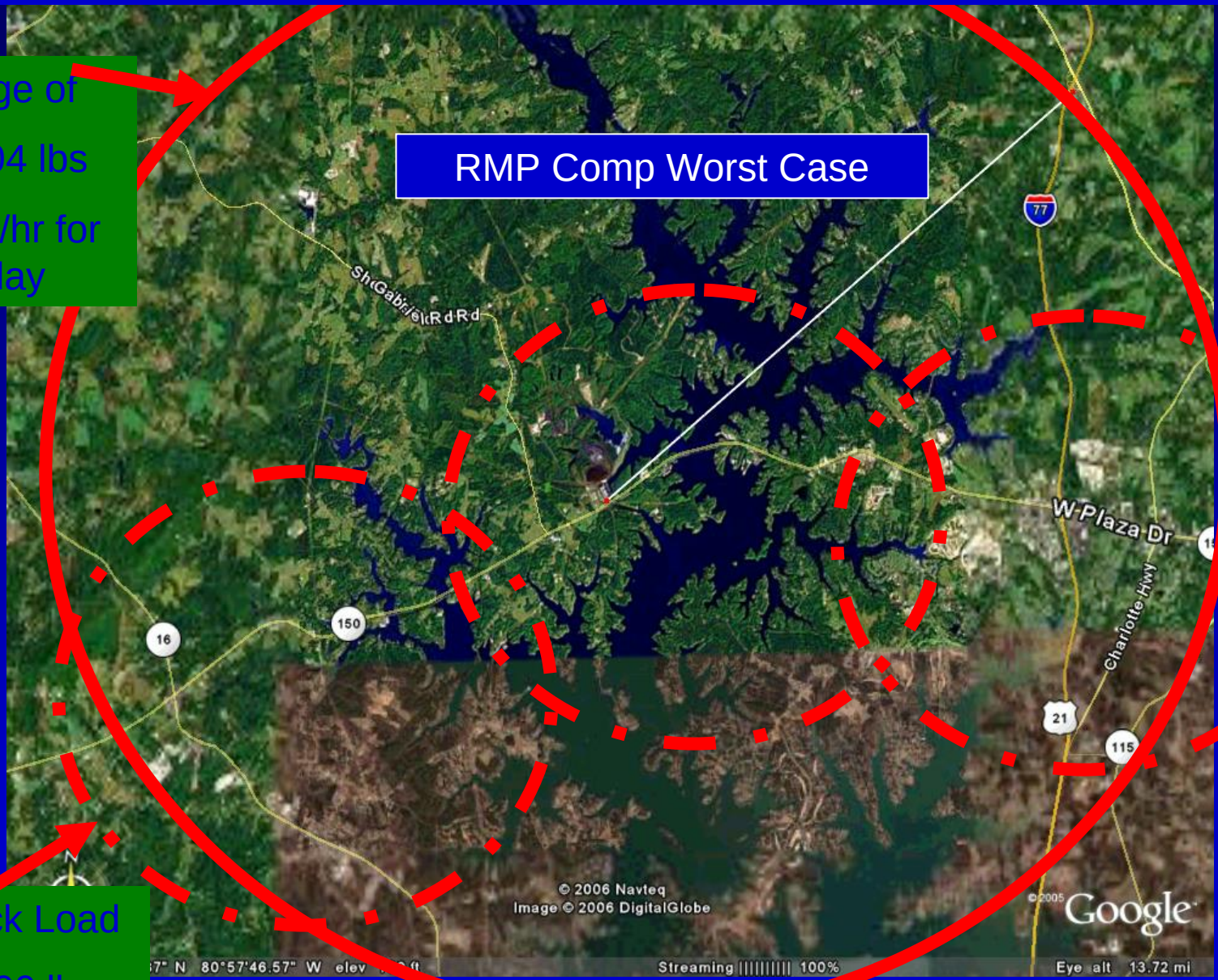


Toxic End Pts for NH3 Spills

Storage of

204,304 lbs

612 lbs/hr for 14 day



1 Truck Load

50,000 lbs

Safety issues with Ammonia

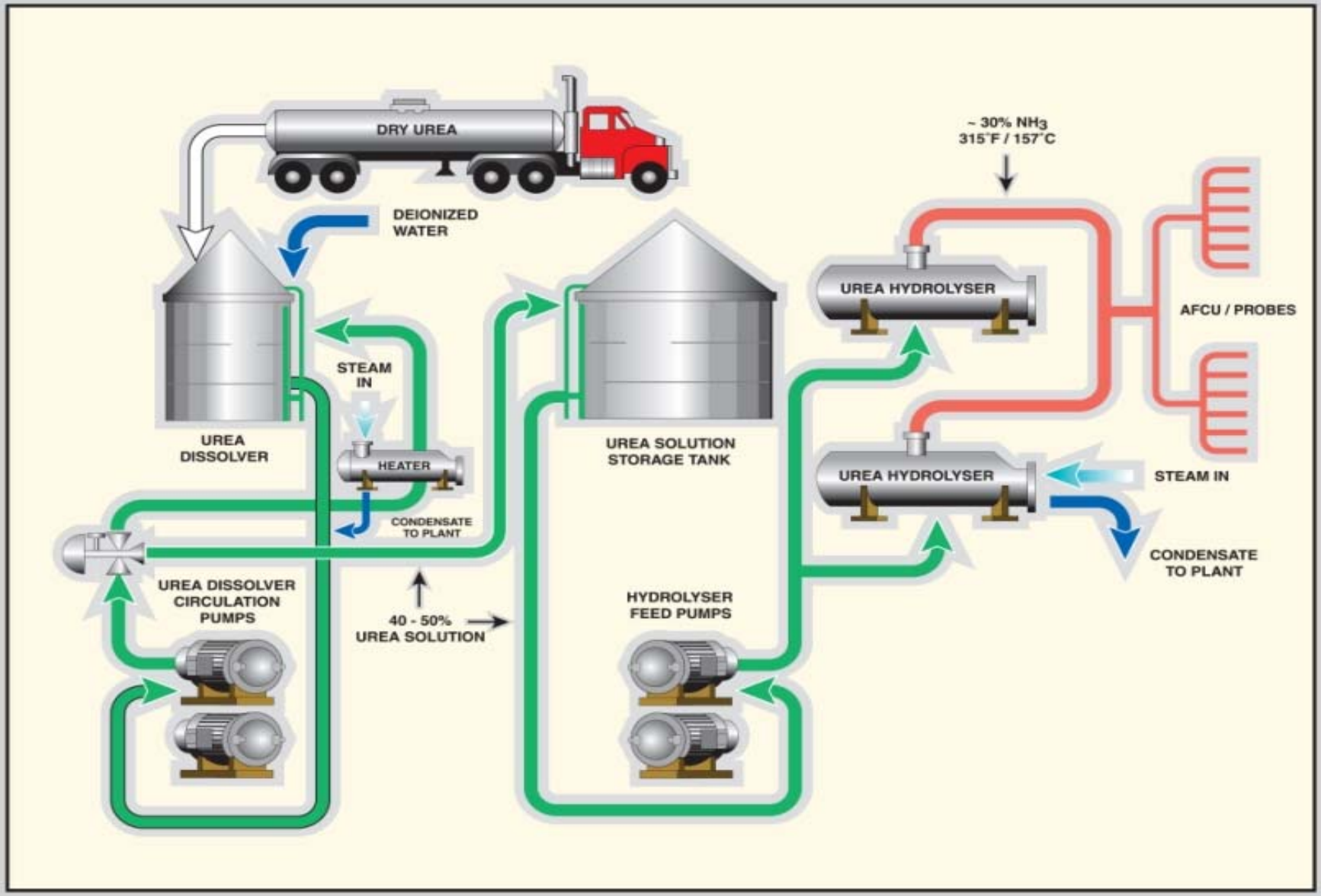
- Per RMP Comp Program
  - Anhydrous truck release 50,000 lbs – toxic endpoint 4 miles
  - 20% Aqueous ammonia truck release 50,000 lbs- toxic endpoint 1.3 miles
  - Five times as many trucks with 20% aqueous ammonia
  - Dry urea deliveries about 1.75 X anhydrous

Safety issues with Urea

- Urea (NH_2CONH_2) Solution
  - Clear, colorless or slightly hazy liquid
  - Light ammonia (pungent) odor
  - Non Flammable
  - Stable Material

Process Description

- Urea Hydrolysis
  - 40 to 50% Urea Pumped to Reactor
  - Heated to about 300°F
  - Pressure of 60 psig
  - 40% Decomposes to:
    - 28.5% Ammonia Vapor
    - 14.3% Carbon Dioxide
    - 57.2% Water Vapor



U2A™ System

WAHLCO, INC.®

Process Requirements

- Urea Hydrolysis
  - 1 lb NH3 per 1.74 lb of Urea
  - 1.3 kW per lb NH3 Theoretical (40% urea)
  - 1.5 kW actual
  - Equivalent steam ~ 6 lb/ lb NH3
  - 50% Urea ~ 20% less
- Urea Solution
  - 40% Requires 2.65 lb Water per lb NH3
  - 50% Requires 1.76 lb Water per lb NH3

Mitchell Hydrolyser

System Improvements

- Reduction in Cost
  - 300 Psig Rating
  - Blow Back to Feed Tank
- Accurate Radar Level Sensing
- Small Footprint
- Simplified Control System

U_2A Features

- Simple Robust System
  - No Catalyst to Replace or Foul
  - No Urea Melters to Maintain
  - Simplest Process
  - Only Two Control Loops
  - Operates at Lower Temperature and Pressure
  - Minimal Reactor Corrosion
  - Conditions Non Conducive to Stress Corrosion
  - Fully Automated Operation

U_2A Features (continued)

- Blowdown Capability
  - Relief to Urea Feed Tank
  - Minimal Ammonia Relief
  - Can be used to reduce contaminant buildup
- Cooling Water for Emergency Shutdown (patented feature)
- Liquid Side Relief
  - To Urea Feed Tank
  - Very fast
  - Minimizes ammonia relief

U_2A Features (continued)

- 99+ % Conversion of Urea to Ammonia
  - No Undesirable By Products to Foul SCR Catalyst
  - Commercial Grade Urea
- No Vaporizer Nozzles to Maintain
- Fast Load Following Response
- Ramp rate 3% per minute

U_2A^{TM} Projects

- 21,000 lb/hr NH3 serving 10,000 MW
  - Allegheny Energy Supply
    - Harrison Station — 3,650 lb/hr
    - Pleasants Station — 1,800 lb/hr
  - AES
    - Alamitos Station — 165 lb/hr
    - Huntington Beach Station — 2 x 360 lb/hr
  - Detroit Edison
    - Monroe Station — 10,000 lb/hr
  - Constellation Energy
    - Wagner Station — 460 lb/hr
    - Brandon Shores Station — 2,500 lb/hr

Power-Gen Innovation Award

Power Engineering Project of the Year

U_2A^{TM} Projects (continued)

- Termokimik
  - Ed Power/Brindisi 1,700 lb/hr
- IST/(Dominion)/Kauai 28 lb/hr
- UCLA 21 lb/hr
- Protecma – Reggio Emelia 22 lb/hr
- White Mountain Energy 85 lb/hr
- City of Spokane 300 lb/hr
- S & W Astoria 258 lb/hr
- Progress Energy
  - Asheville Station Unit 2 820 lb/hr

U_2A^{TM} Projects (New)

- Mid American Energy
  - Council Bluffs Unit 4 — 800 lb/hr
- AEP
  - Mitchell Station Units 1 & 2 — 3500 lb/hr
  - Conesville Station Unit 4 — 1700 lb/hr
- Moneypoint Power Station — 2860 lb/hr
- Mirant Morgantown — 2650 lb/hr
- Sinclair Oil — 6 lb/hr
- Duke Marshall 3 — 810 lb/hr
- Seminole Electric — 2176 lb/hr

Urea

- Urea (NH2CONH2)
  - Essentially harmless to the environment
  - Safely transported, stored and handled
- Readily available bulk commodity chemical
  - Used as fertilizer, in plastics, in adhesives and in pharmaceuticals
  - Available in solid form or as commercial solution
- Economical alternative to aqueous ammonia
  - Urea is 56% ammonia (equivalent)
  - Significantly less expensive to operate than 19% aqueous
  - Approximately equivalent operating cost to 29% aqueous

Urea Production

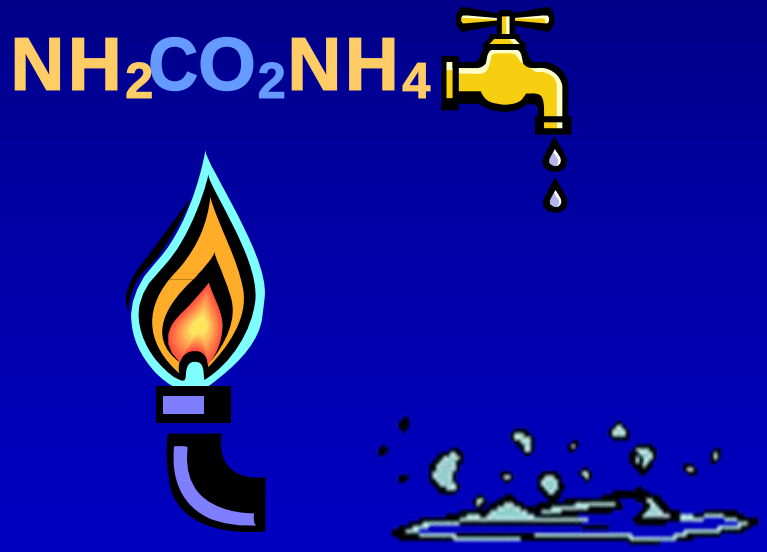
NH_3 CO_2 NH_3

Urea Production

$NH_2CO_2NH_4$

Ammonium Carbamate

Urea Production



Ammonium Carbamate

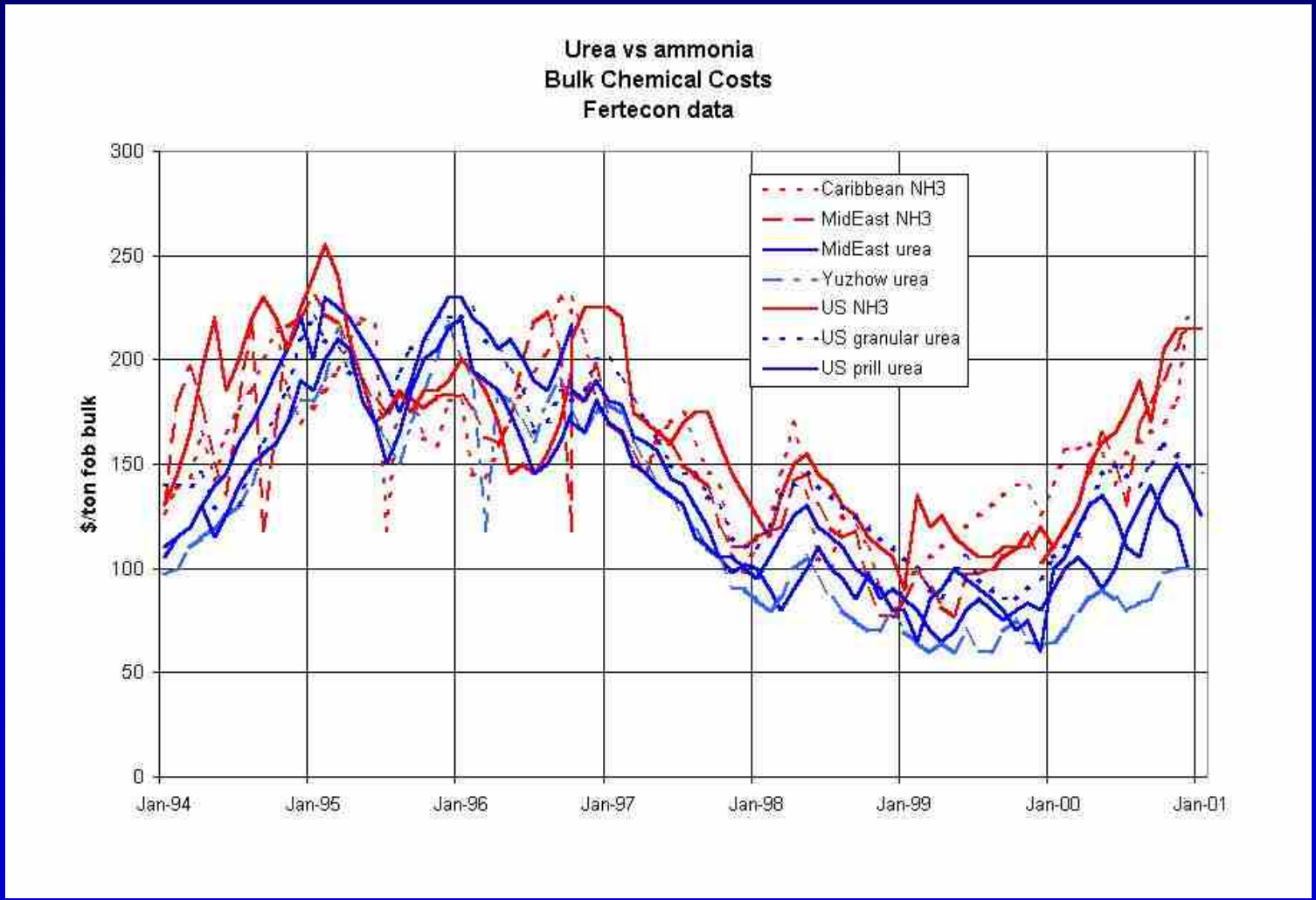
Urea Production

NH_2CONH_2

UREA

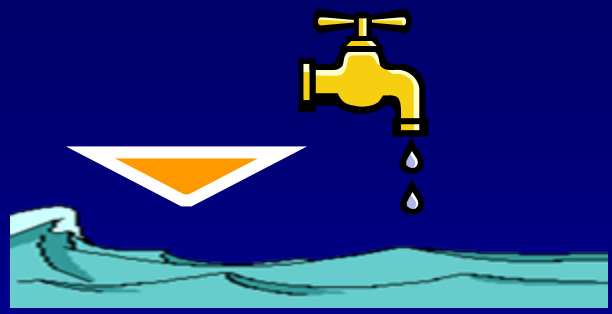
Urea vs. Ammonia - chemical cost

– Ammonia and urea track with natural gas prices



TURNING UREA BACK INTO AMMONIA

Urea back to Ammonia



Urea back to Ammonia

$H_2O + NH_2CONH_2 = NH_2CO_2NH_4$

Ammonium Carbamate

Urea back to Ammonia

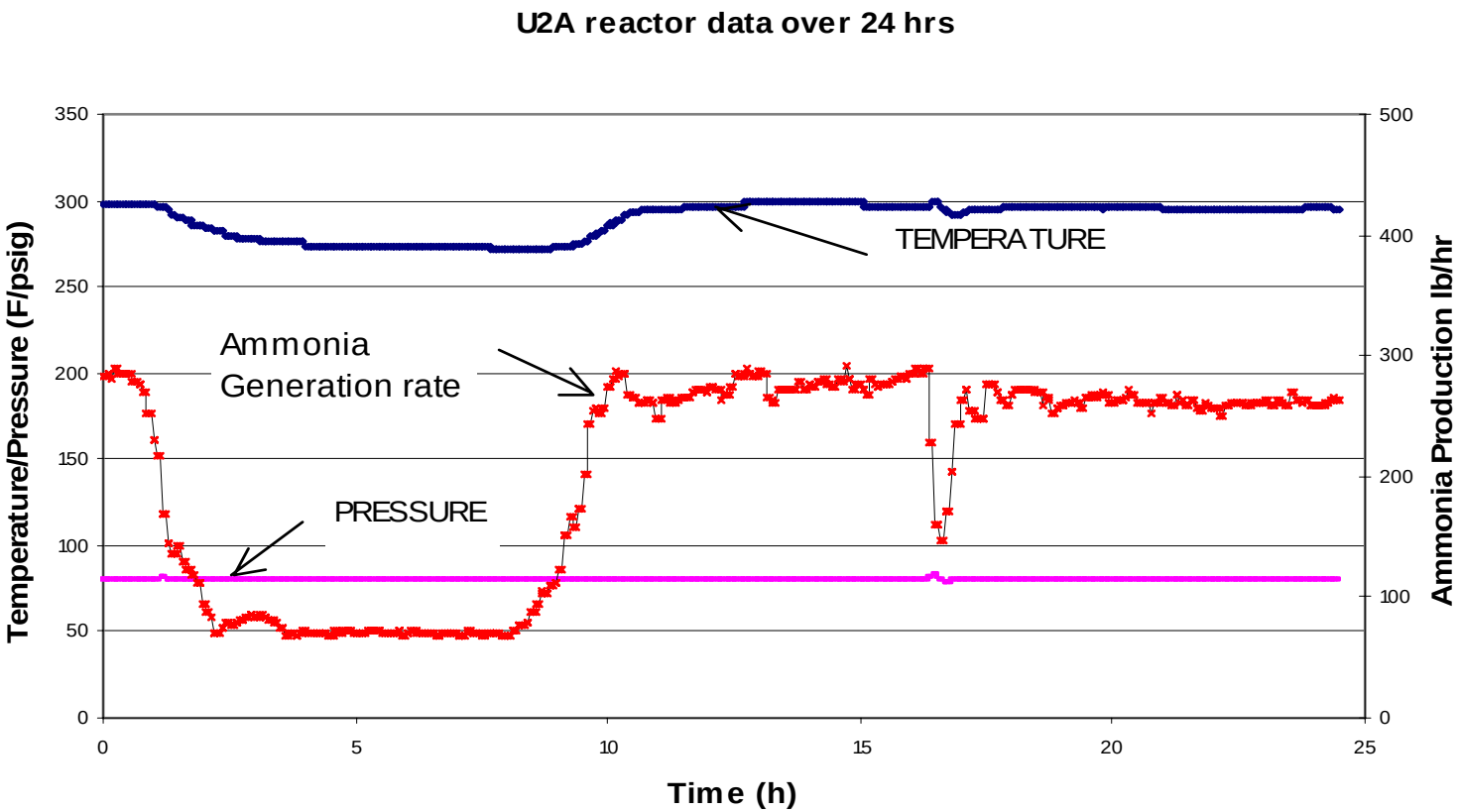
NH_3 CO_2 NH_3

Ammonia and Carbon Dioxide


OPERATION

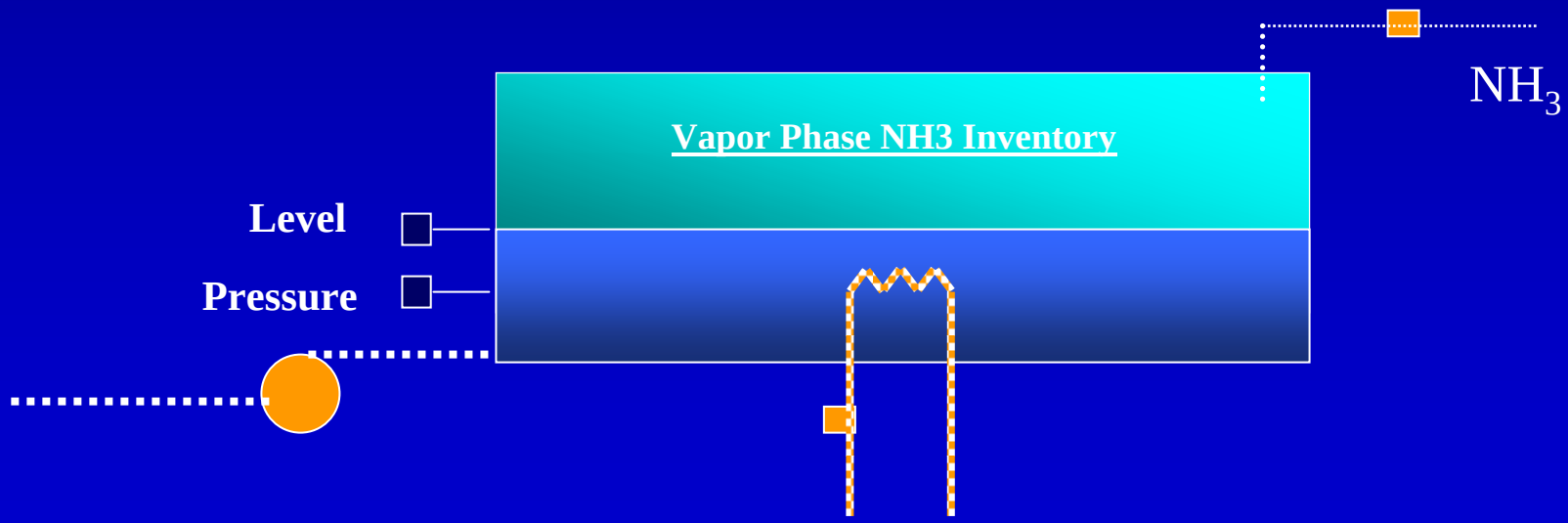
Load Following Data

- Process easily follows boiler load variations
  - CPSG Wagner Station



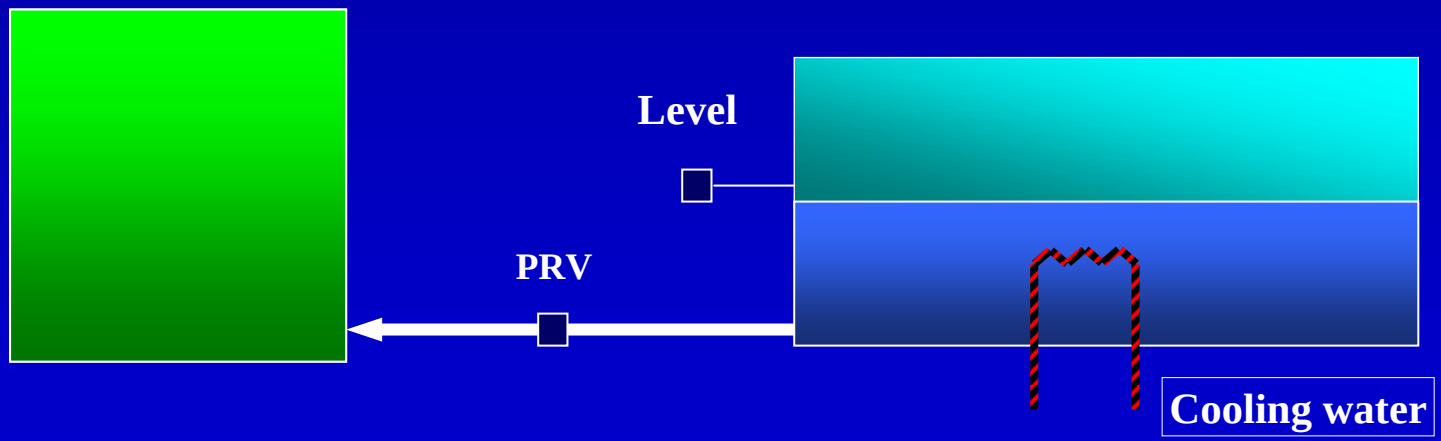
U_2A^{TM} Process Shutdown

- Normal shutdown
  - NH_3 to process continues
  - Shut off Steam control valve
  - Shut off Feed pump
  - Hold NH_3 control valve minimum open to bleed pressure
  - Reactor enters standby or idle mode



Fast Shutdown

- Emergency shutdown (no gas released from reactor)
  - Steam control valve shutoff
  - Feed pump shutoff
  - Cooling water introduced to coils
- PSV shutdown
  - Pressure relief valve set point reached
  - Partial release of liquid feed tank quenches reaction




INSPECTION

Internal Inspections

- Wagner end of season residue (~ 100 days of use)

Steam Bundle Inspections

- Wagner steam bundle as removed from reactor

Steam Bundle Inspections

- Wagner reactor steam bundle after steam cleaning


MATERIAL HANDLING

Delivery Options

- Solution
  - Lower capacity requirements satisfied with commercially prepared urea solutions
  - Typically ~5,500 Gallons per delivery
  - 70% Urea Liquor
- Dry Urea by Truck
  - Truck capacity typically 25 tons
  - Pneumatic self unloading trucks
- Dry Urea by Rail
  - Rail car capacity typically 100 tons
  - Closed hopper cars require pneumatic or mechanical unloading

Urea Material Handling

- Dry Storage
  - Large projects – issues with storage time
  - Silos
    - Shippable 12’ x 75’ – 9000 cf
    - Dehumidified silo purge
    - 14 day storage
  - Critical to Empty at Close of Season

Urea Material Handling

- Solution Storage
  - Solution Tank
    - commercial solution for small capacity projects
  - Dissolver
    - Truck load capacity
    - 1 truck load ~ 1 day at 1000 lb/hr NH3
    - Multiple dissolvers typical

Design Considerations

- Determine feed type
  - Granular Urea
  - Solution 40%, 50% or 70%
  - Heat tracing considerations
- Feed delivery schedule
  - Delivery vehicle size
  - How many deliveries per day
  - Dissolver feed pumps, DI water and heaters sized

Design Considerations

- Basic Equipment Configuration
  - Most Projects use 2 X 100% Hydrolysers
  - One operating other ‘standby’
  - Some projects use 3 X 50%
- Equipment location issues
  - Hydolysers close to Urea Storage
    - Blow down / relief considerations
    - If distant a quench tank may be required
    - Product Gas Heat tracing considerations

Utilities

- Steam
  - 225 psig saturated best
  - Up to 50 deg F superheat ok
  - Can design for as low as 140 psig
  - Required ramp rate sizes peak steam flow
  - Requires 5 to 6 lbs of steam per lb of ammonia produced
- Electric
  - May be used for heat tracing
  - Pumps and instruments
- DI Water
- Plant Air
- Cooling Water

Questions