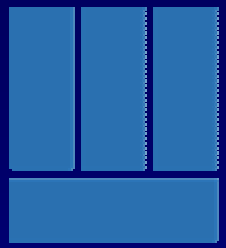
Reinhold Environmental Ltd.

2008 NOx-Combustion Round Table & Expo Presentation

February 4-5, 2008 in Richmond, VA



WAHLCO, INC.®

Urea to Ammonia Technology

U_2A^{TM}

NOx Roundtable

February 5, 2008

U_2A^{TM} System

- U_2A^{TM} (urea to ammonia): Reducing risks associated with ammonia handling:
  - Eliminates the hazards from: 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
  - Easier and less expensive to permit
  - (U.S. patents 6,077,491, 6,322,762, 6,436,359 and
  - 6,506,350; European and Asian patents issued or pending)

Ammonia Systems for DeNOx

- Began Marketing in 1998
- Utility and Gas Turbine Applications
- Unloading, Storage tanks, Vaporizers, AIG ~160 systems sold
  - 45 Anhydrous
  - 78 Aqueous
  - 37 U2A Systems (15,000 mW)

DeNOx Feed Stock Comparisons

- Anhydrous Ammonia
  - Lowest Capital and Operating Costs
  - Most Difficult to Permit
  - Effect of Future Restrictions Unknown
  - Lethal Chemical Safety Issues
- Aqueous Ammonia
  - Higher Capital and Operating Costs
  - Less Difficult Permitting Issues
  - Less Toxic than Anhydrous but more handling involved

Feed Stock Comparisons

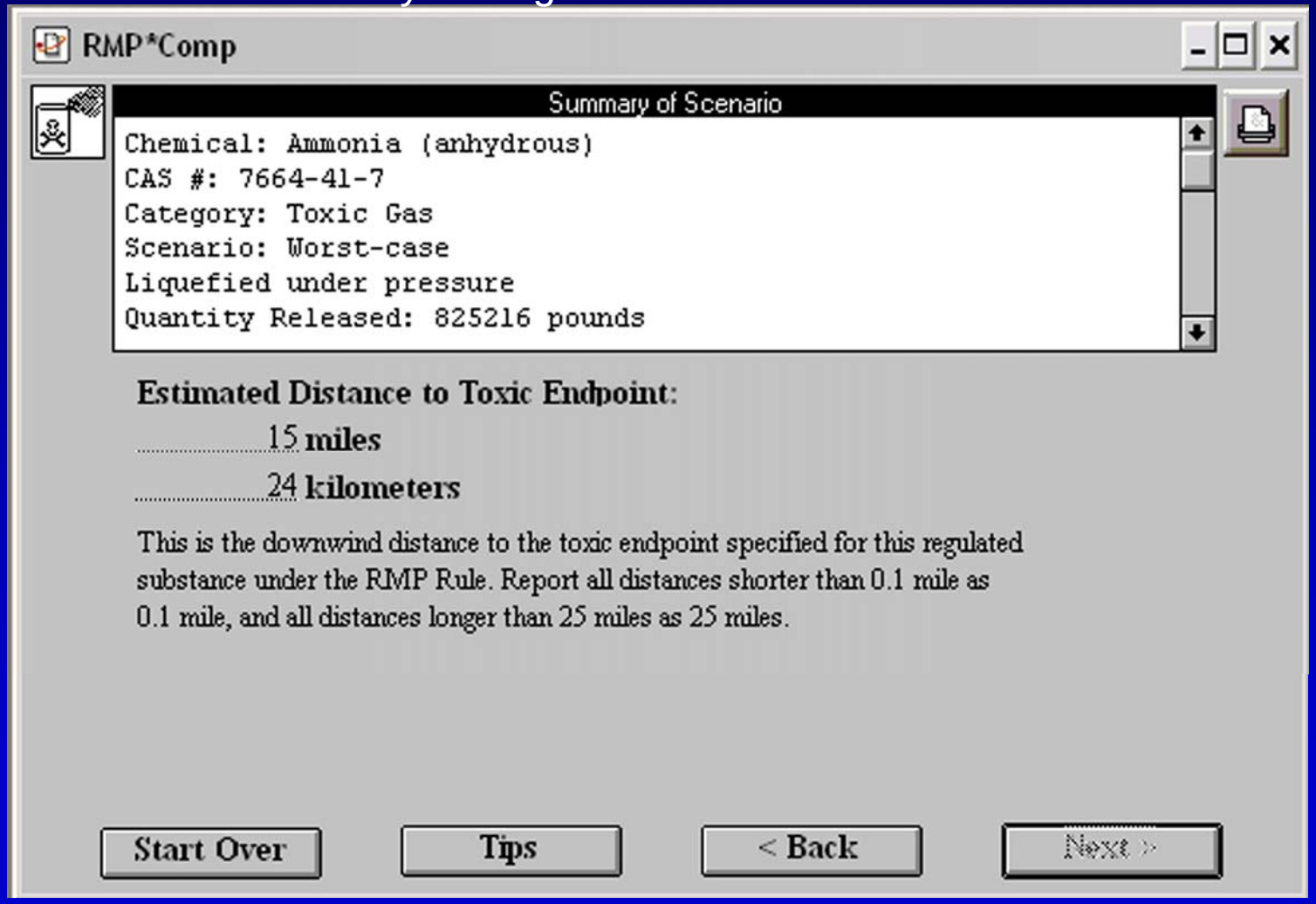
- Urea
  - Capital Costs Similar to 19% Aqueous Ammonia System
  - Operating Costs less than 19% Aqueous
  - Permitting not an Issue
  - Ammonia is produced as needed
  - Storage of Ammonia is below reporting threshold
  - Feed stock is non toxic

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

EPA RMP Comp

14 Day Storage for 4 units each 612 lb/hr



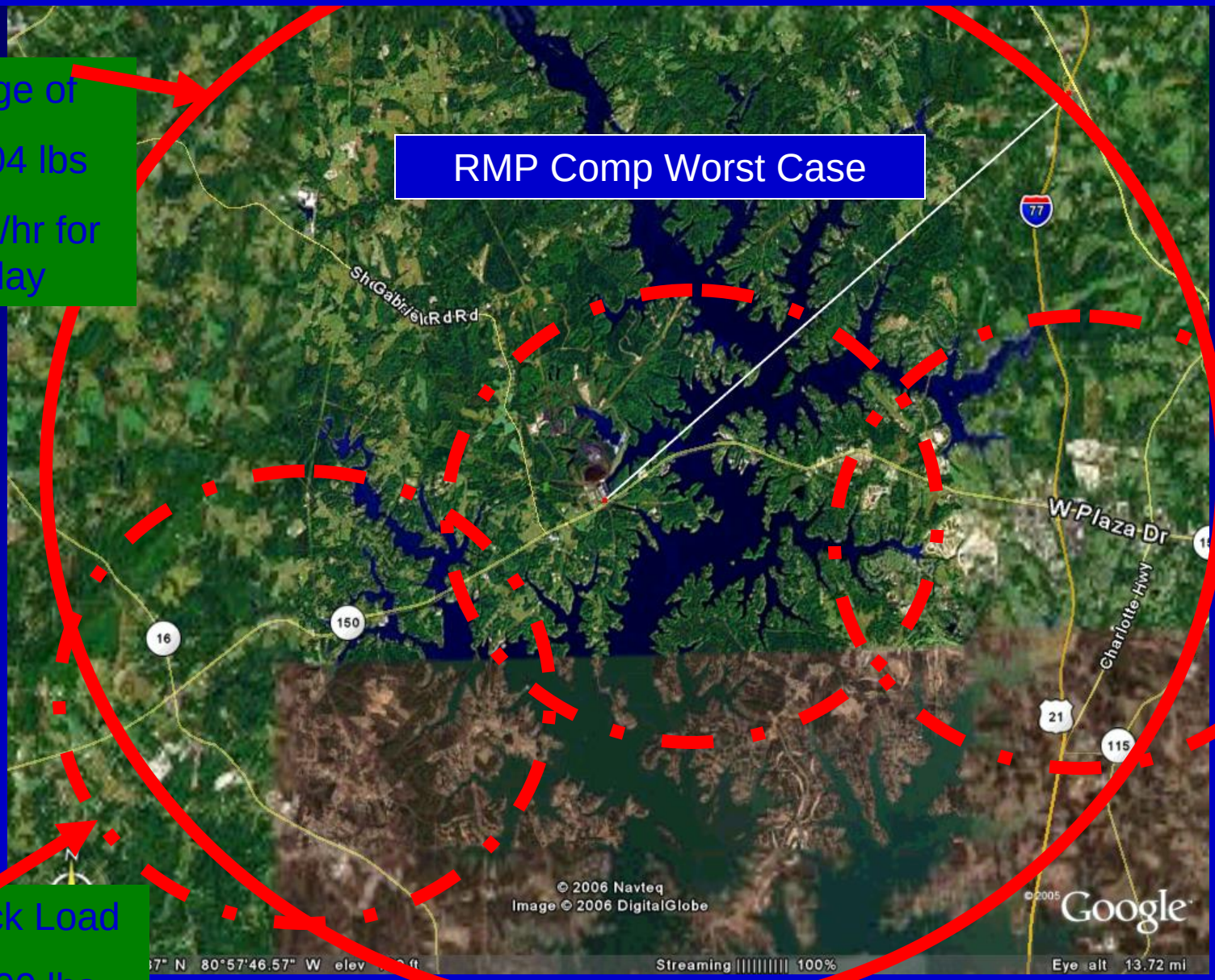
Toxic End Pts for NH3 Spills

Storage of

204,304 lbs

612 lbs/hr for 14 day

RMP Comp Worst Case

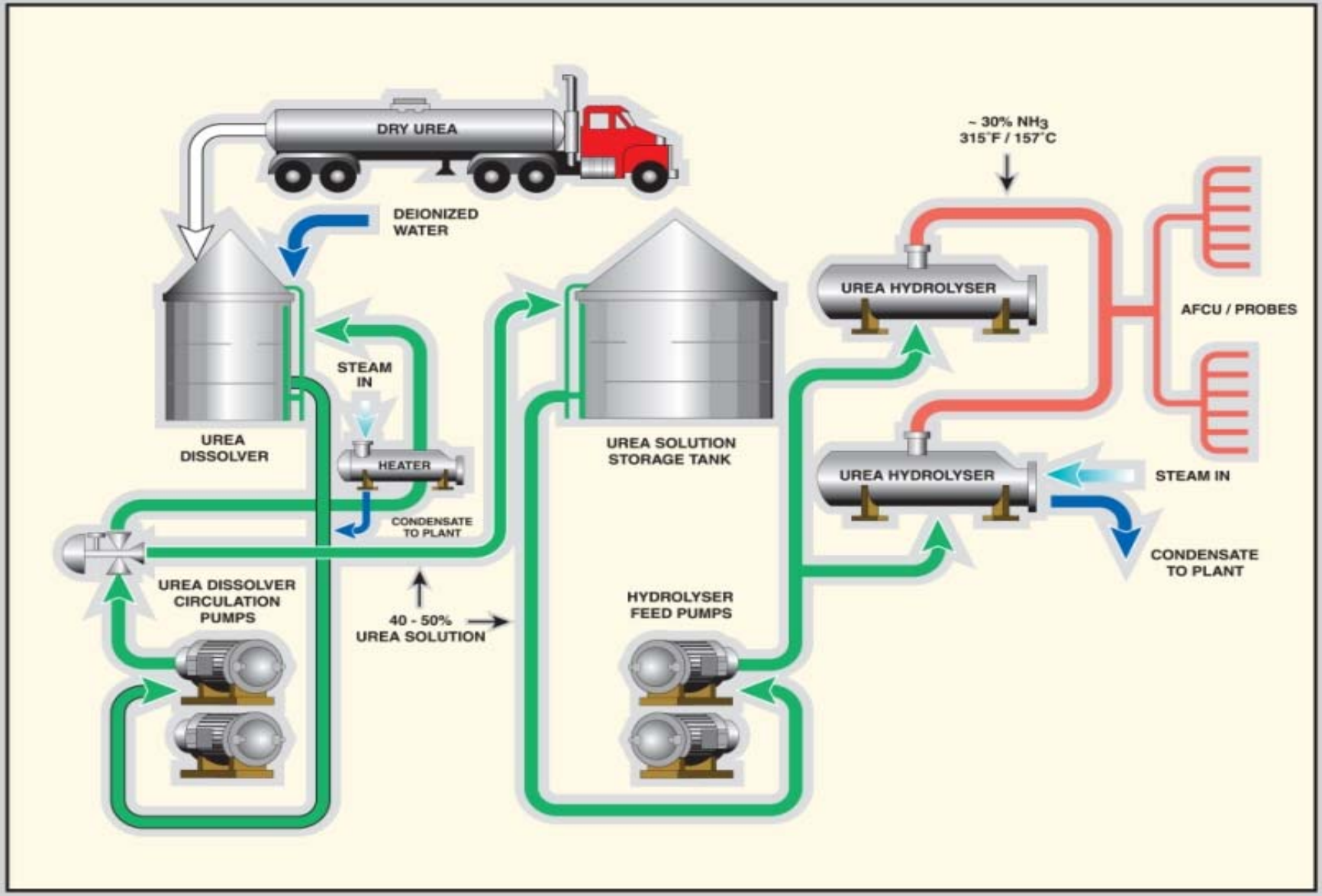


1 Truck Load

50,000 lbs

Safety

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



U2A™ System

WAHLCO, INC.®

Process Description

- Urea Hydrolysis
  - 40 to 50% Urea Pumped to Reactor
  - Heated to about 300°F
  - Pressure of 60 to 80 psig
  - 40% Decomposes to (by volume):
    - 28.5% Ammonia Vapor
    - 14.3% Carbon Dioxide
    - 57.2% Water Vapor

Process Requirements

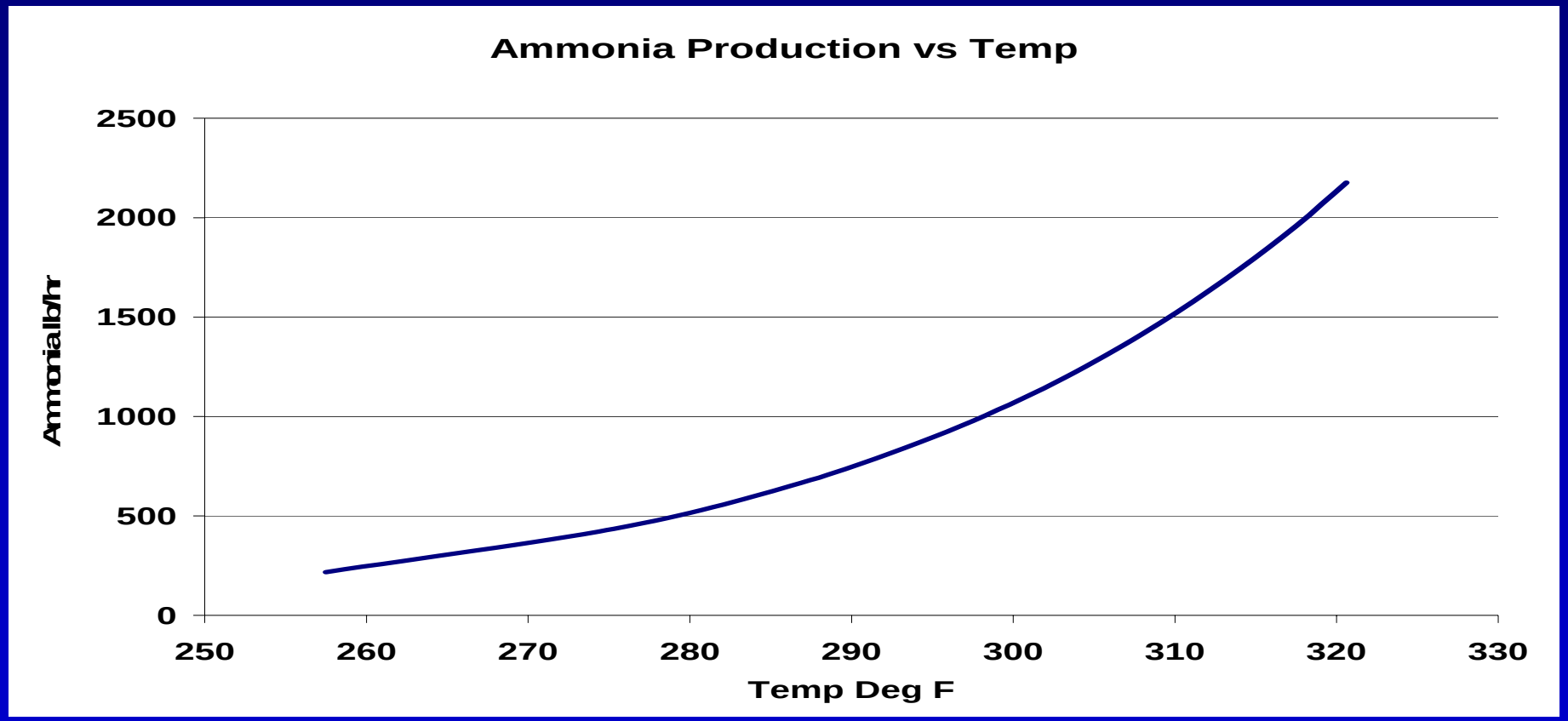
- Urea Hydrolysis
  - 1 lb NH3 per 1.74 lb of Urea
  - 1.3 kW per lb NH3 Theoretical (40% urea)
  - 1.5 kW actual
  - Equivalent steam ~ 6 lb/ lb NH3
  - 50% Urea ~ 20% less
- Urea Solution
  - 40% Requires 2.65 lb Water per lb NH3
  - 50% Requires 1.76 lb Water per lb NH3

Process Description

- Process Gas
  - Piping heat traced to 320 deg F
  - Avoid Water Dew point
  - Avoid forming ammonia carbamate

Production rate vs Temperature

- Hydrolyser temperature increases with production rate
- At high rates production doubles with 10 deg F



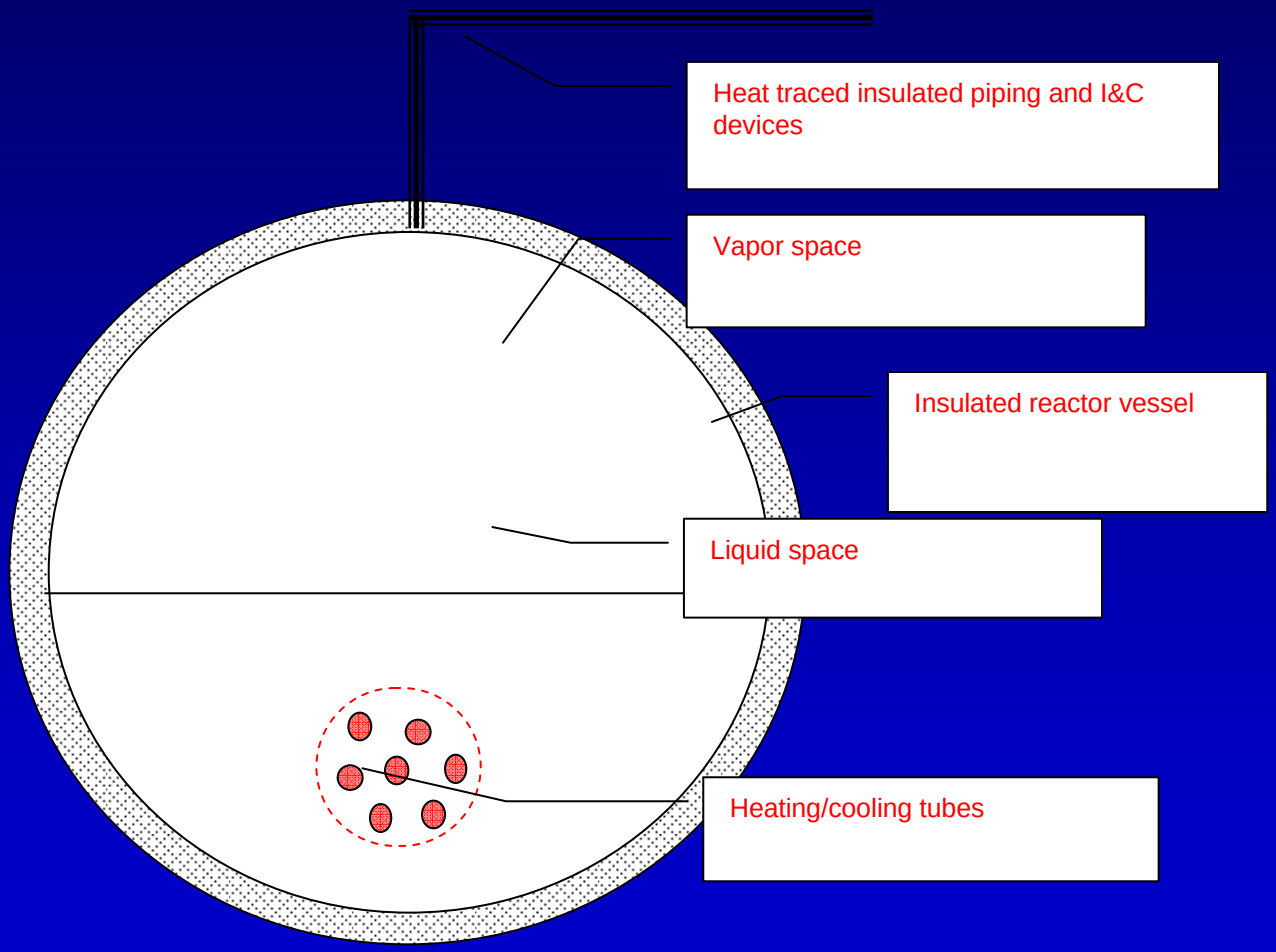
Operating Principles

- Heat modulated to achieve set pressure
- Hydrolyser temperature increases with production rate
- Steam flow increases with production rate
- Pressure required to maintain correct water balance

Steam Characteristics

- Steam should be saturated
- Typical design pressures 120 psig -225 psig
- Hydrolyser maximum temperature function of steam inlet temp and coils
- Operating pressure of hydrolyser not a function of steam pressure

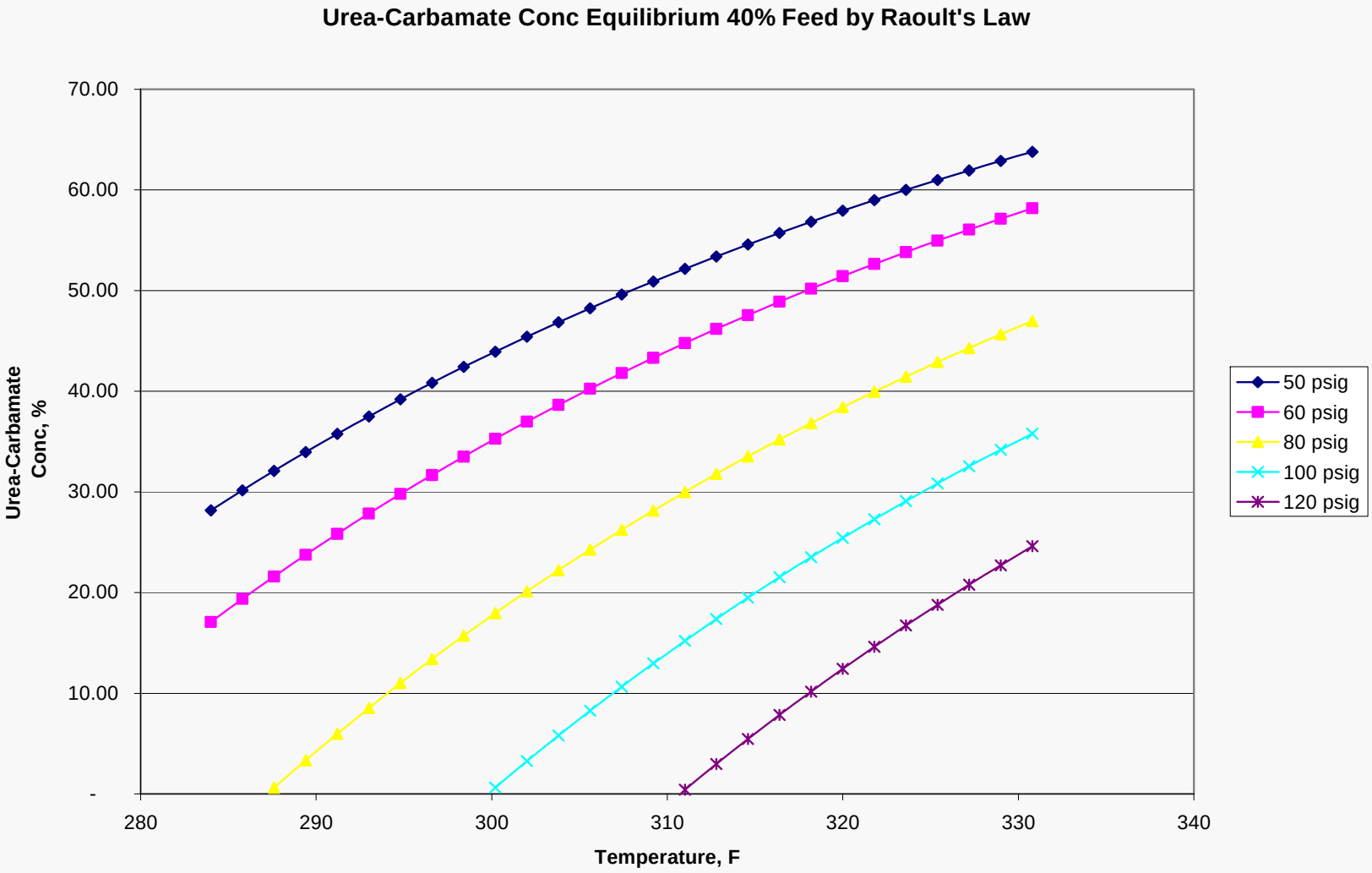
Reactor Cross Section



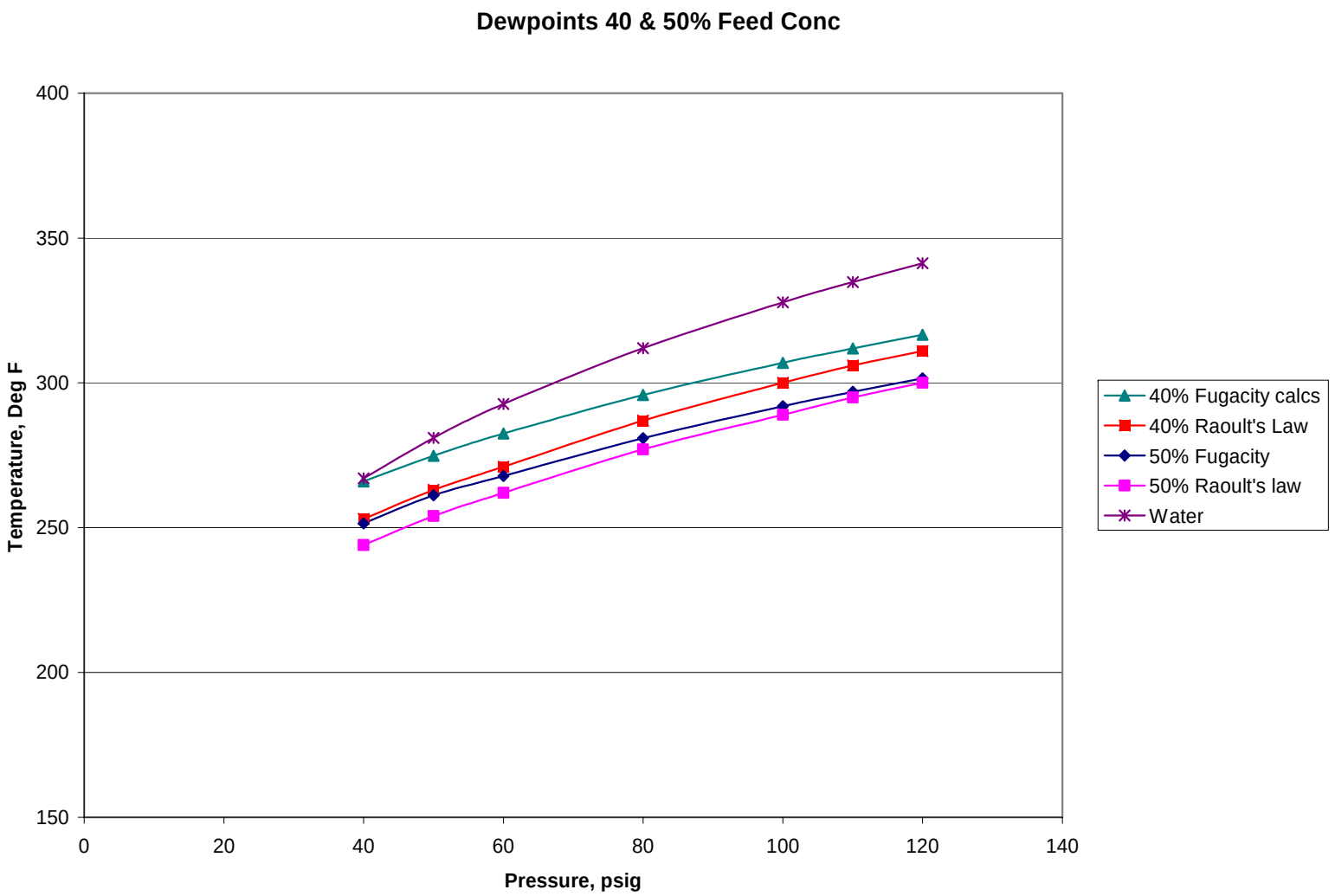
Hydrolysis Water Balance

- Water required for hydrolysis reaction
- At steady state conditions water equilibrium is reached in hydrolyser.
- Proper pressure required to maintain correct ratio of water in hydrolyser.

Water Balance 40% feed



Dewpoint Comparisons



Feed Stock Quality Issues

- SCR Catalyst Poisons
  - Injected Ammonia must be fairly pure
  - Contaminants can cause injector plugging
  - Catalyst Guarantees require virtually no phosphorus, arsenic & other metals
  - Issues with ammonia purity on all feed stocks
- Urea to Ammonia Hydrolyser
  - Captures non volatile materials
  - All urea has some metals and other impurities
  - DI water impurities
  - Blow down system included to mitigate hydrolyser buildups

Mitchell Hydrolyser

Recent Improvements

- Accurate Radar Level Sensing
- Blow down system to remove contaminants
- Low Energy Consumption
- 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)

- Blow Back Capability
  - Relief to Urea Feed Tank
  - Minimal Ammonia Relief
  - Can be used to reduce contaminant buildup
- Blow Down System
  - Blow Down Dependent upon urea purity
  - Blow down may be discharged to drain
- Cooling Water for Emergency Shutdown (patented feature)
- Liquid Side Relief
  - To Urea Feed Tank
  - Very fast
  - Minimizes ammonia release

U_2A Features (continued)

- 99+ % Conversion of Urea to Ammonia
  - No Undesirable By Products to Foul SCR Catalyst
  - All non volatile contaminants are captured in the hydrolyser and do not go into the SCR
  - Urea typically has 10 to 100 ppm of heavy metal contaminants that could poison the catalyst if allowed into the SCR
  - Commercial Grade Urea
- No Vaporizer Nozzles to Maintain
- Fast Load Following Response
- Ramp rate 4% per minute

U_2A^{TM} Projects

- 38,000 lb/hr NH3 serving over 15,000 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
- Williams Pipeline 90 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

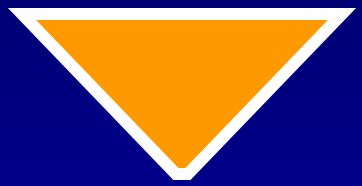
U_2A^{TM} Projects (New)

- Mid American Energy
  - Council Bluffs Unit 4 — 604 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
- Hitachi Seminole — 2176 lb/hr
- Namjeju Korea — 160 lb/hr
- Crystal River — 2266 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

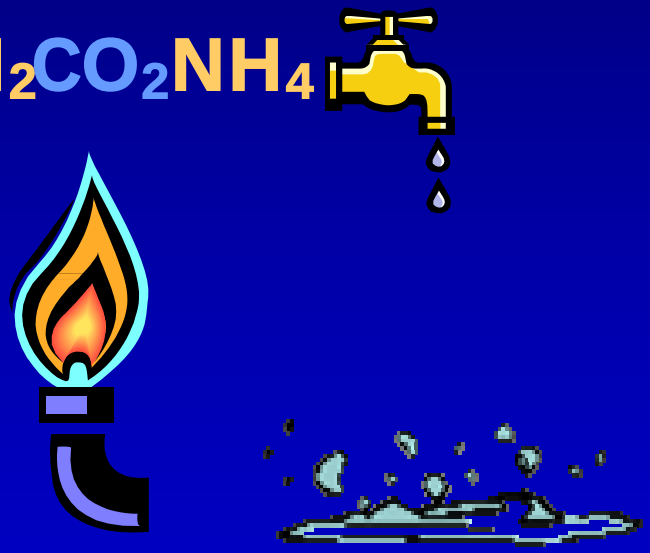
Urea Production

$NH_2CO_2NH_4$

Ammonium Carbamate

Urea Production

$NH_2CO_2NH_4$



Ammonium Carbamate

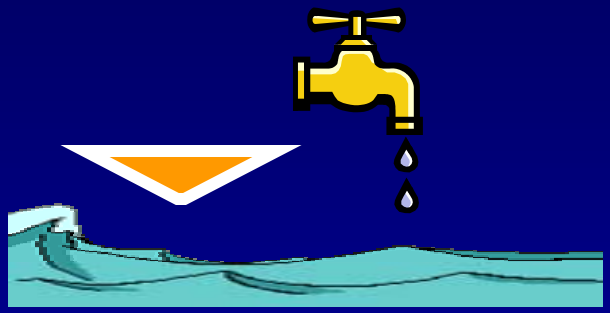
Urea Production

NH_2CONH_2

UREA

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

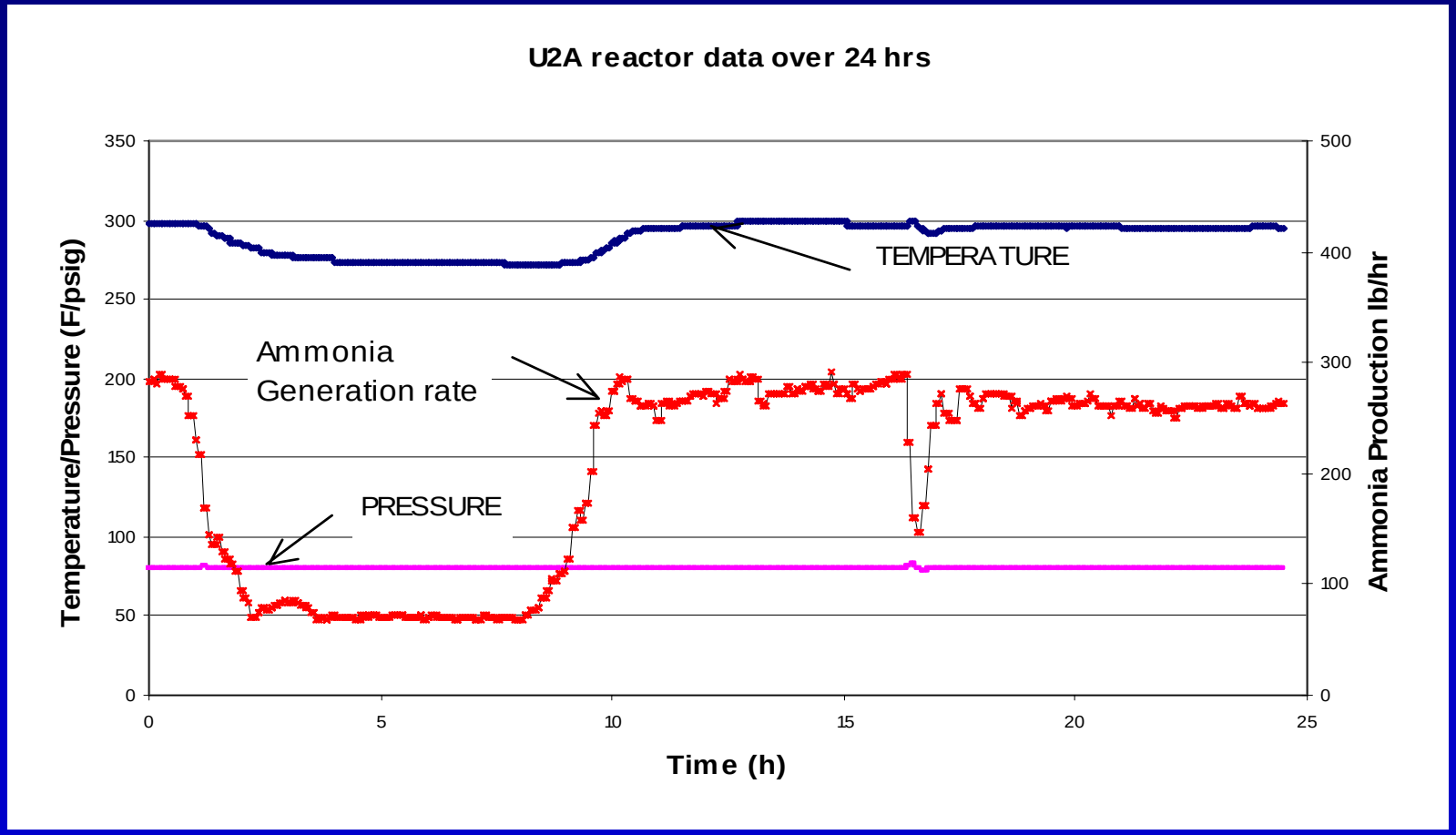
NH_3 CO_2 NH_3

Ammonia and Carbon Dioxide

OPERATION

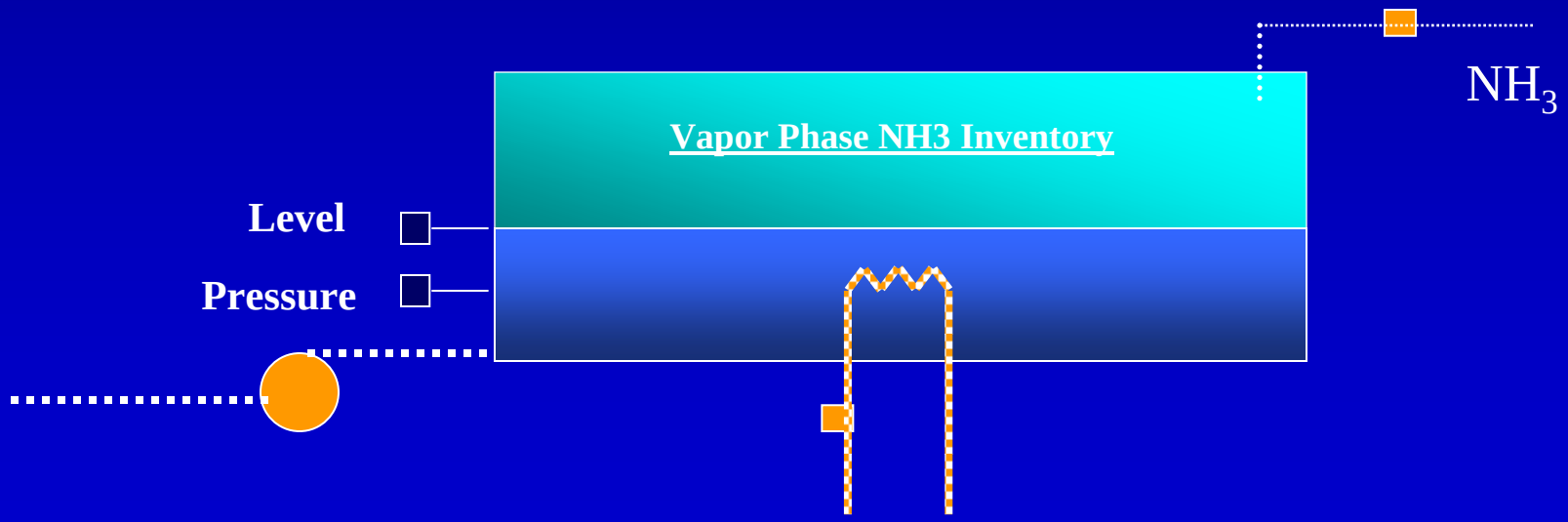
Load Following Data

- Process easily follows boiler load variations
  - CPSG Wagner Station



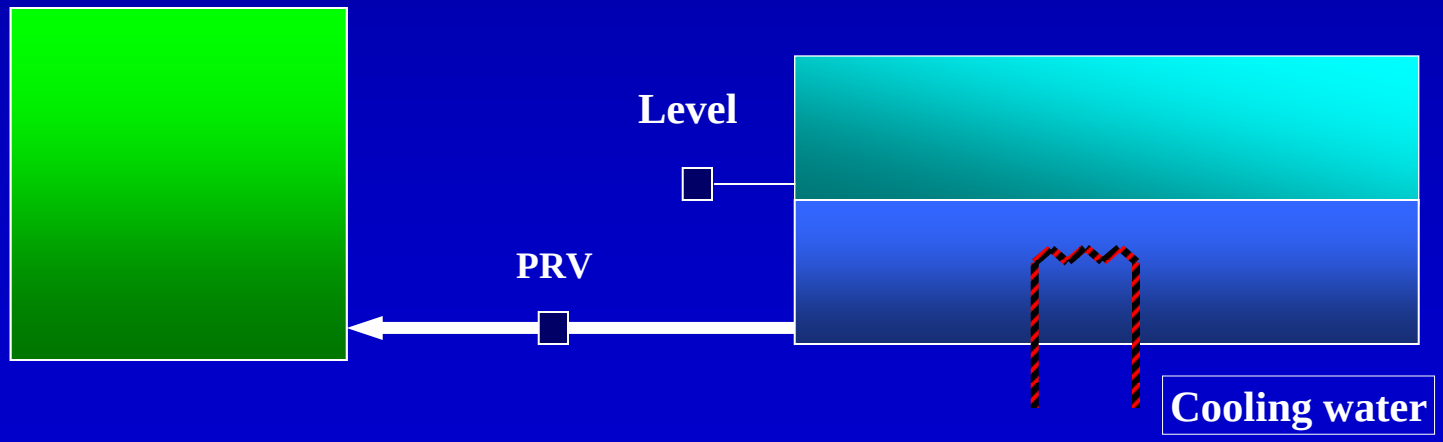
U_2A^{TM} Process Shutdown

- 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
- Blow down valve or PRV shutdown
  - Pressure relief valve set point reached
  - Partial release of liquid feed tank quenches reaction



Blow Down

- Urea Impurities Concentrate in Hydrolyser
  - Metals in urea feed
  - Impurities from DI water
  - Handling / transportation contaminants
- Frequency of Removal
  - Urea Quality
  - Operating Rate
- Periodic Draining of Hydrolyser
- Partial Blow Down to Blow Down Tank

Internal Inspections

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

Steam Bundle Inspections

- Wagner steam bundle as removed from reactor

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

EXPERIENCE

Current Operation

- **Operational**
  - **AES Huntington Units 1 thru 4**
  - **Detroit Monroe Unit 1 thru 4**
  - **Constellation Wagner**
  - **IST/Dominion – Kauai**
  - **Allegheny Harrison Unit 1 thru 3**
  - **UCLA**
  - **Allegheny Pleasants Unit 1 & 2**
  - **Constellation Brandon Shores**
  - **White Mountain Energy**
  - **Protecma – Reggio Emelia**
  - **Wheelabrator –Spokane**
  - **Termokimik –Brindisi**
  - **Astoria Energy**
  - **Mid American Council Bluffs**
  - **Asheville Station**
  - **Mirant Morgantown**
  - **Sinclair Oil**
  - **Termokimik AMSA**
  - **Termokimik- IMOLA**

Questions