REINHOLD ENVIRONMENTAL Ltd.

2011 NOx-Combustion Round Table & Expo Presentation

February 7-8, 2011, in Birmingham, AL / Hosted by Southern Company

WAHLCO, Inc.

Urea to Ammonia Systems Safety and Economics

2011 NOx Roundtable
February 8, 2010

NOx Reduction Requirements

- SCRs Required all New Fossil Units
- Increasing regulations for Industrial Applications
- Many SCR's Required in 2011 to 2012

NOx Reduction Technology

- Low NOx Burner
- SNCR's
  - Urea Based
  - Aqueous Ammonia
  - Anhydrous Ammonia
- SCR's
  - Anhydrous Ammonia
  - Aqueous Ammonia
  - Urea to Ammonia

DeNOx Reagents

- Somewhat Depends upon System Type
- SNCR's boiler temperatures influence selection
  - Direct Urea Injection Most Common
  - Some systems use aqueous or anhydrous ammonia
  - Urea to Ammonia can replace anhydrous ammonia
- SCR Technology
  - Temperatures usually not conducive for direct urea injection
  - Anhydrous Ammonia
  - Aqueous Ammonia
  - Urea to Ammonia

Feed Stock Issues

- Equipment Capital Costs
- Operating Costs
  - Feedstock
  - Energy
  - Manpower Requirements
- Permitting and Safety Related Issues

Ammonia Feed Stocks

- Urea
  - Supplied Dry
  - 70% Solution
  - 40% Solution
- Aqueous Ammonia
  - Concentrations from 19 to 29%
  - Above 19% requires pressure vessel

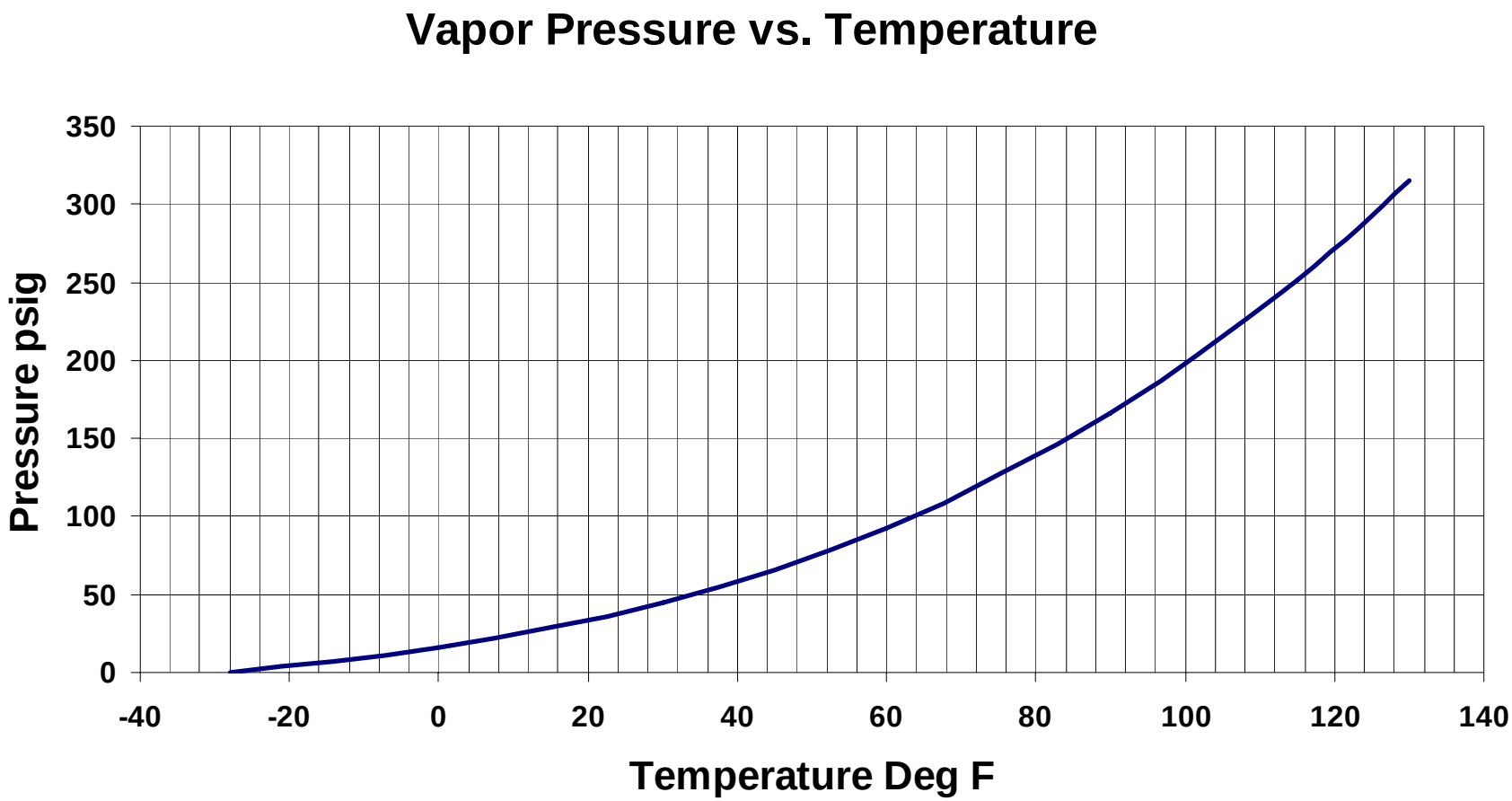
Anhydrous Ammonia

- Anhydrous = Very little water (0.2-0.5%)
- Pungent, colorless gas
- Stored as liquid under pressure (or refrigerated)
- Flammable compressed gas
- Pressure varies greatly with temperature
  - e.g. 50º F ≈ 72 psig ; 90º F ≈ 160 psig

Anhydrous Properties

- Density @ 60 deg F ~ 38.5 lbs/ ft3
- Explosive Limits 16 to 25% in air
- Boiling point -28 deg F
- Energy to Vaporize ~ 540 btu/ lb
- National Response Center Notification with 100 lb release
- Lethal Limit 5 minutes at 5000 ppm

Anhydrous Ammonia



Anhydrous NH3 Safety Issues

- Anhydrous Ammonia highly toxic lethal chemical
- Almost 10,000 accidental releases in ten years
- Storage entails high liability
- Regulated by Homeland Security
- Requires Coded Pressure Vessels
- Transportation costs rapidly increasing due to Liability issues – can not be trucked in many areas

AQUEOUS AMMONIA SYSTEMS

Aqueous Ammonia

- Ammonium Hydroxide (NH_4OH)
- Various Concentrations
  - 29.4%, 25%, 19.5%, 11% others
  - At 29% Pressure Vessel Required
- Liquid
- Low pressure
  - at 100º F = 10 psig (29.4%)
- 7.3 lb/gal (29.4% solution)

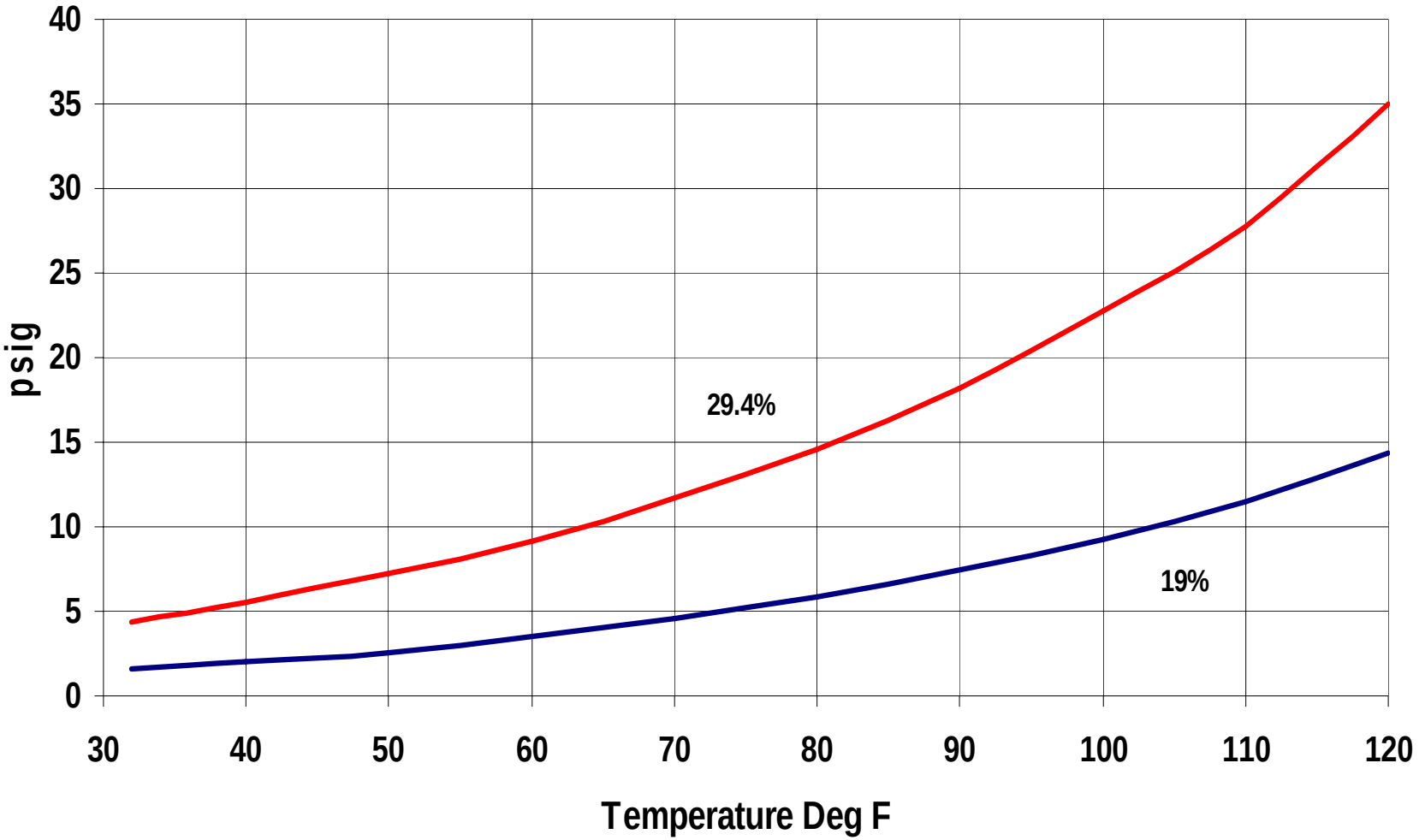
Aqueous Ammonia 19%

- National Response Center Notification with 1000 lb release (190 lbs of ammonia)
- Required EPA risk management plan for >20% and 20,000 lbs
- Freezing point ~ -30 deg F
- Heat of Vaporization ~ 981 btu's/lb (5163 btu's / 1 lb NH3
- Must keep vaporized mixture above dewpoint to point of use

Aqueous Ammonia 29.4%

- Requires coded pressure vessel
- Freezing point ~ -110 deg F
- Heat of Vaporization ~ 929 btu's/lb (3160 btu's / 1 lb NH3
- Must keep vaporized mixture above dewpoint to point of use

Aqueous Ammonia



Aqueous Ammonia Safety Issues

- Regulated toxic chemical
- EPA RMP toxic release distances 1/3 to 1/2 of Anhydrous Ammonia
- Large Storage Volumes
- Increased Transportation Handling Risk

Safety Considerations of Ammonia

U2A®

www.wahlco.com
714-979-7300

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

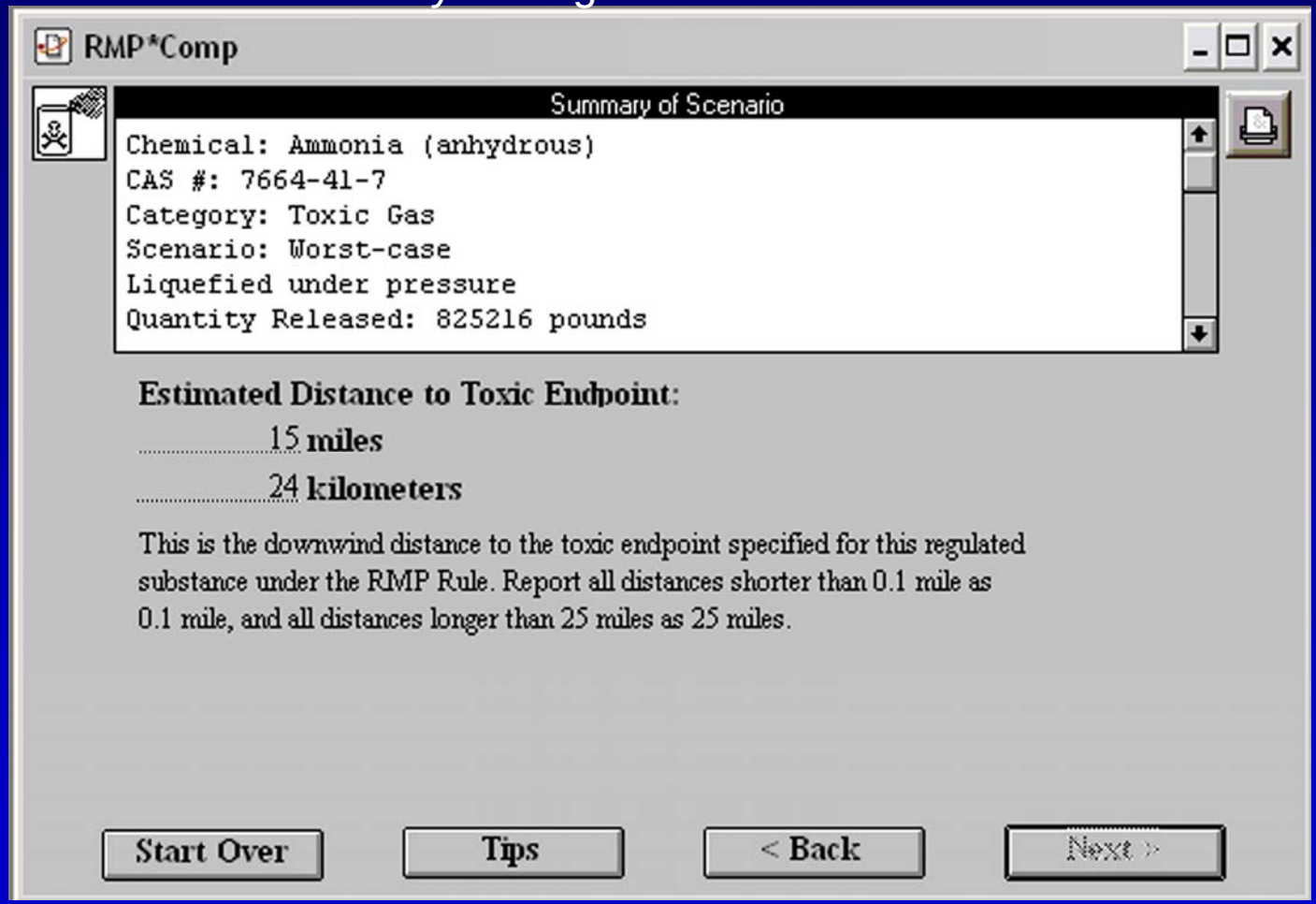
The reality of disaster . . .

From NTSB – Pipeline Accident Brief
Accident No.: DCA05-MP001
Date: October 27, 2004
Material Released: Anhydrous Ammonia
Location: 6 miles west of Kingman, Kansas

- Ammonia pipeline accident near Kingman, Kansas (population 3,387 as of 2000)
- 204,000 gallons released
- Ammonia aerosol cloud formed that traveled close to the ground
- **Severe Hazard** – one breath of aerosol cloud vapor would have been **immediately fatal**

EPA RMP Comp

14 Day Storage for 4 units each 612 lb/hr

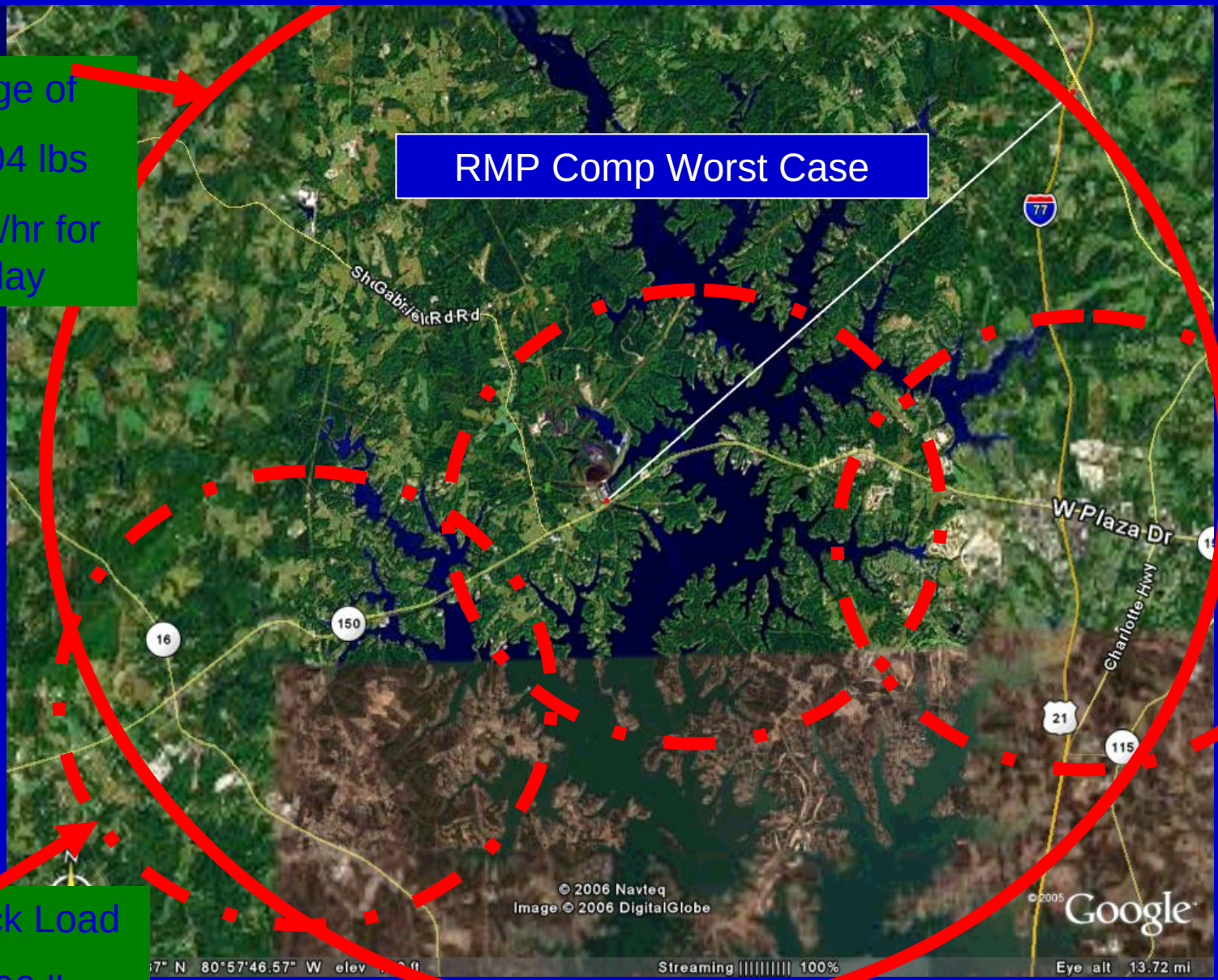


Toxic End Pts for NH3 Spills

Storage of

204,304 lbs

612 lbs/hr for 14 day



1 Truck Load

50,000 lbs

U_2A® Technology

- Process Converts Urea to Ammonia on Site
- U_2A® (urea to ammonia): Reduces risks associated with ammonia handling:
- (U.S. patents 6,077,491, 6,322,762, 6,436,359 and 6,506,350; European and Asian patents issued or pending)

Why U_2A®

- U_2A® (urea to ammonia): Reduces risks associated with ammonia handling:
- Eliminates the hazards from: shipping, handling, transfer or storage of ammonia
- Easier and less expensive to permit
- New Railroad Regulations will make Ammonia much more Expensive
  - Armor front of Rail Cars
  - Reduce max speed to 35 mph

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
  - Significantly less expensive to operate than 19% aqueous

Urea Production

NH_3 CO_2 NH_3

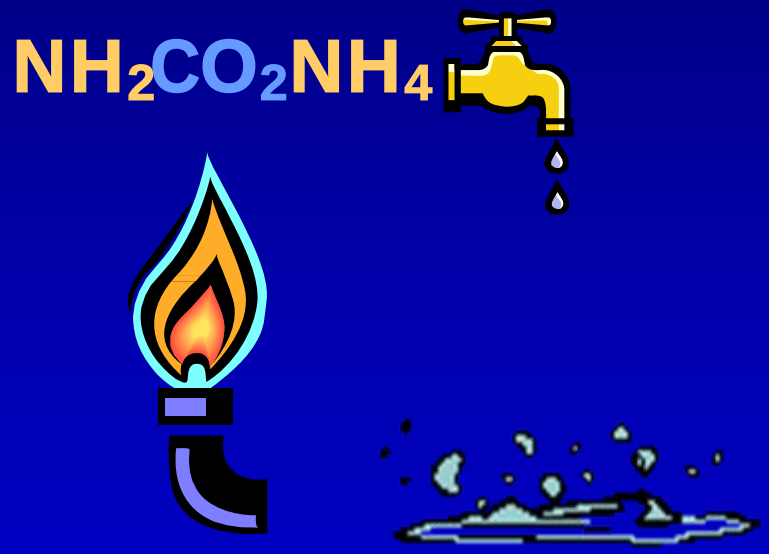
www.wahlco.com
714-979-7300

Urea Production

$NH_2CO_2NH_4$

Ammonium Carbamate

Urea Production



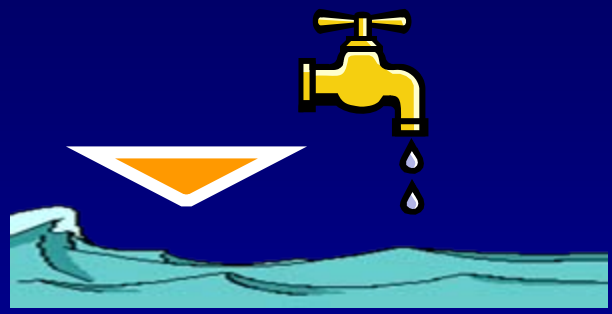
Ammonium Carbamate

Urea Production

NH_2CONH_2

UREA

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, Carbon Dioxide &
Water Vapor

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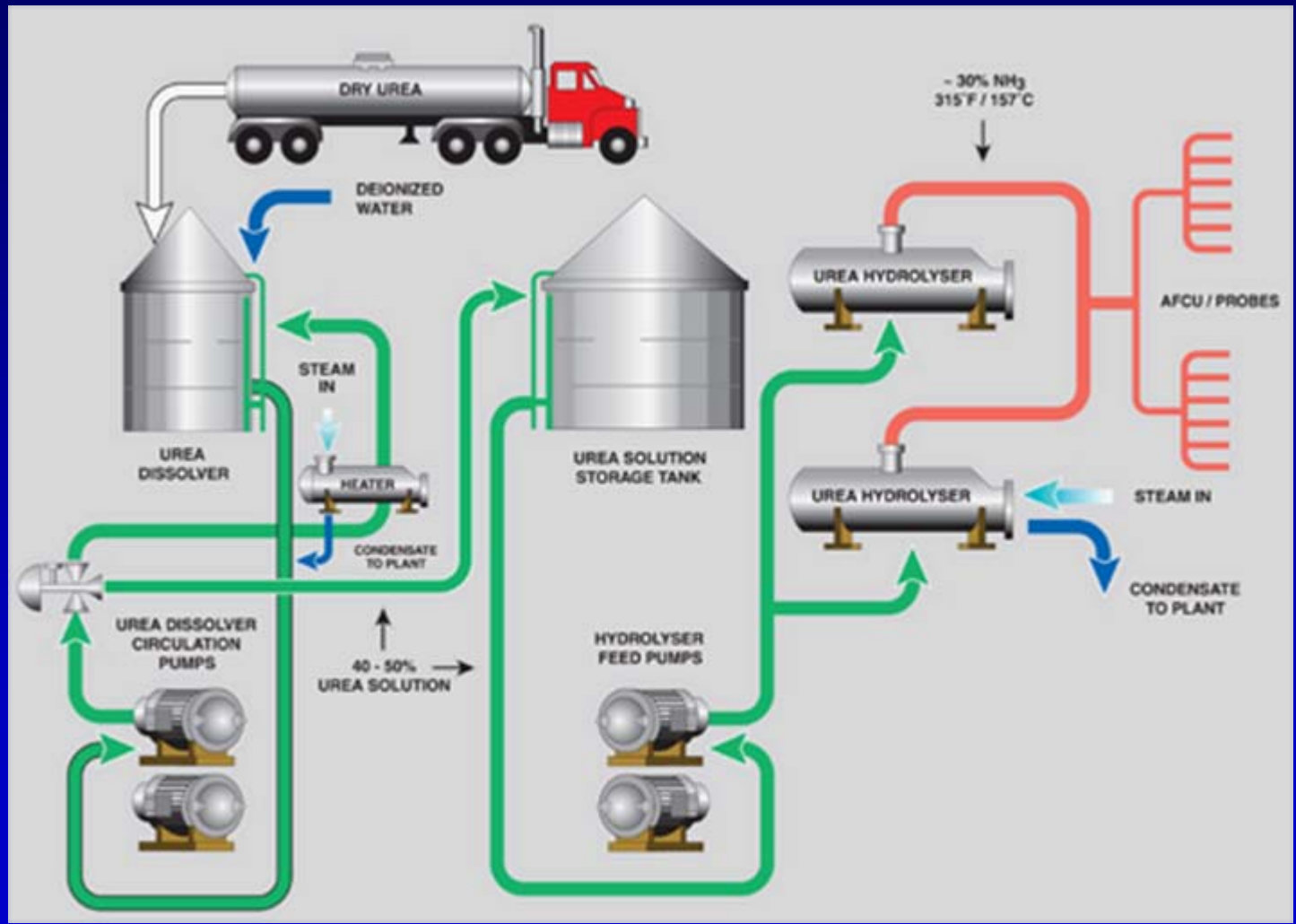
How does U2A® work?



Dissolve Urea
(Urea + Water)

↓

Hydrolyze
Urea Solution

↓

Deliver Product Gas
(on-demand)

Process Description

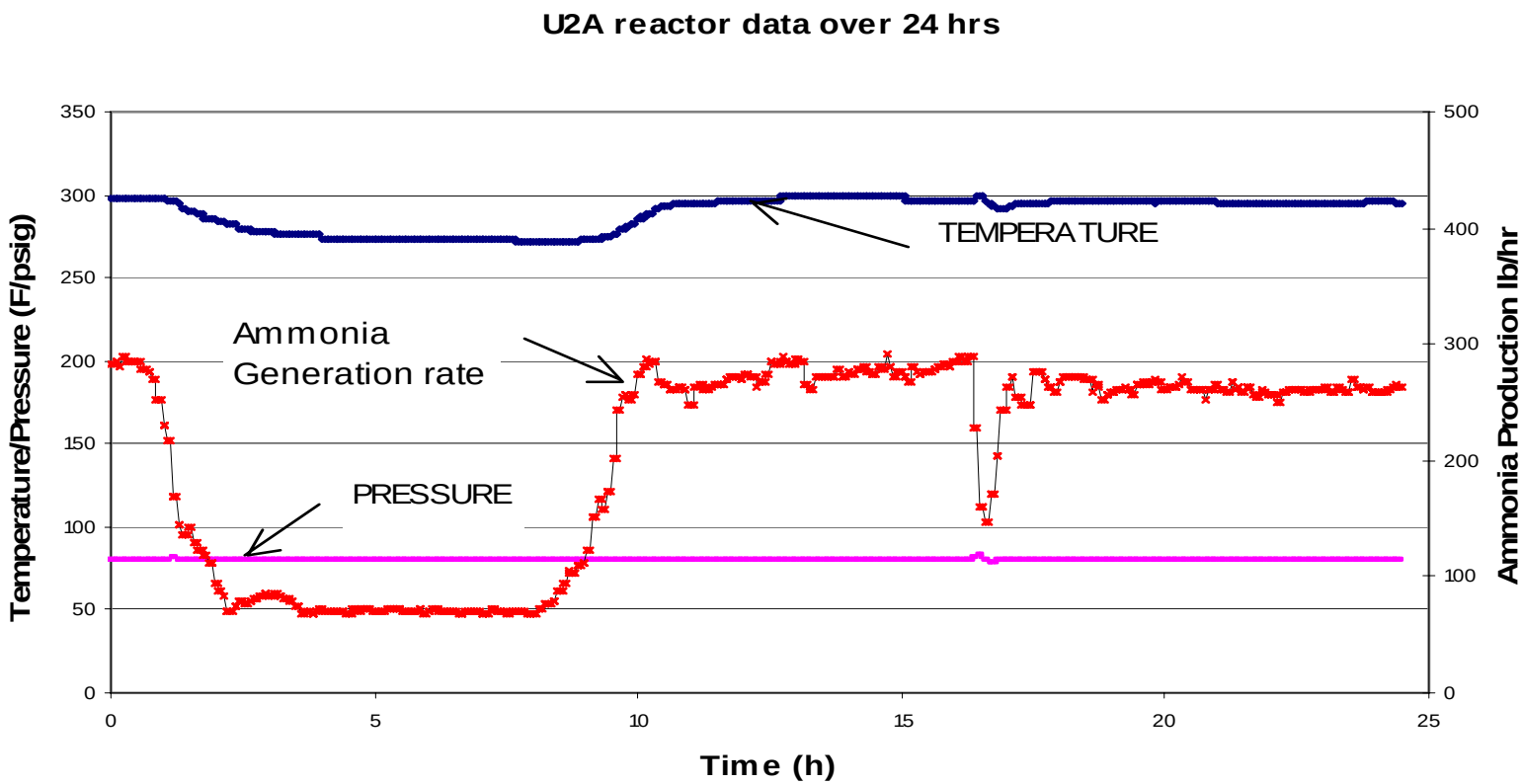
- Urea Hydrolysis
  - 40 to 50% Urea Pumped to Reactor
  - Heated to about 300°F
  - Pressure of 40 to 120 psig
  - 40% Decomposes to:
    - 28.5%Vol. Ammonia Vapor
    - 14.3%Vol. Carbon Dioxide
    - 57.2%Vol. Water Vapor

Process Requirements

- Urea Hydrolysis
  - 1 lb NH3 per 1.74 lb of Urea
  - For 40% Solution
    - Steam ~ 6 lb/ lb NH3
    - 20% less Steam for 50%
- Urea Solution
  - 40% Requires 2.65 lb Water per lb NH3
  - 50% Requires 1.76 lb Water per lb NH3

Load Following Data

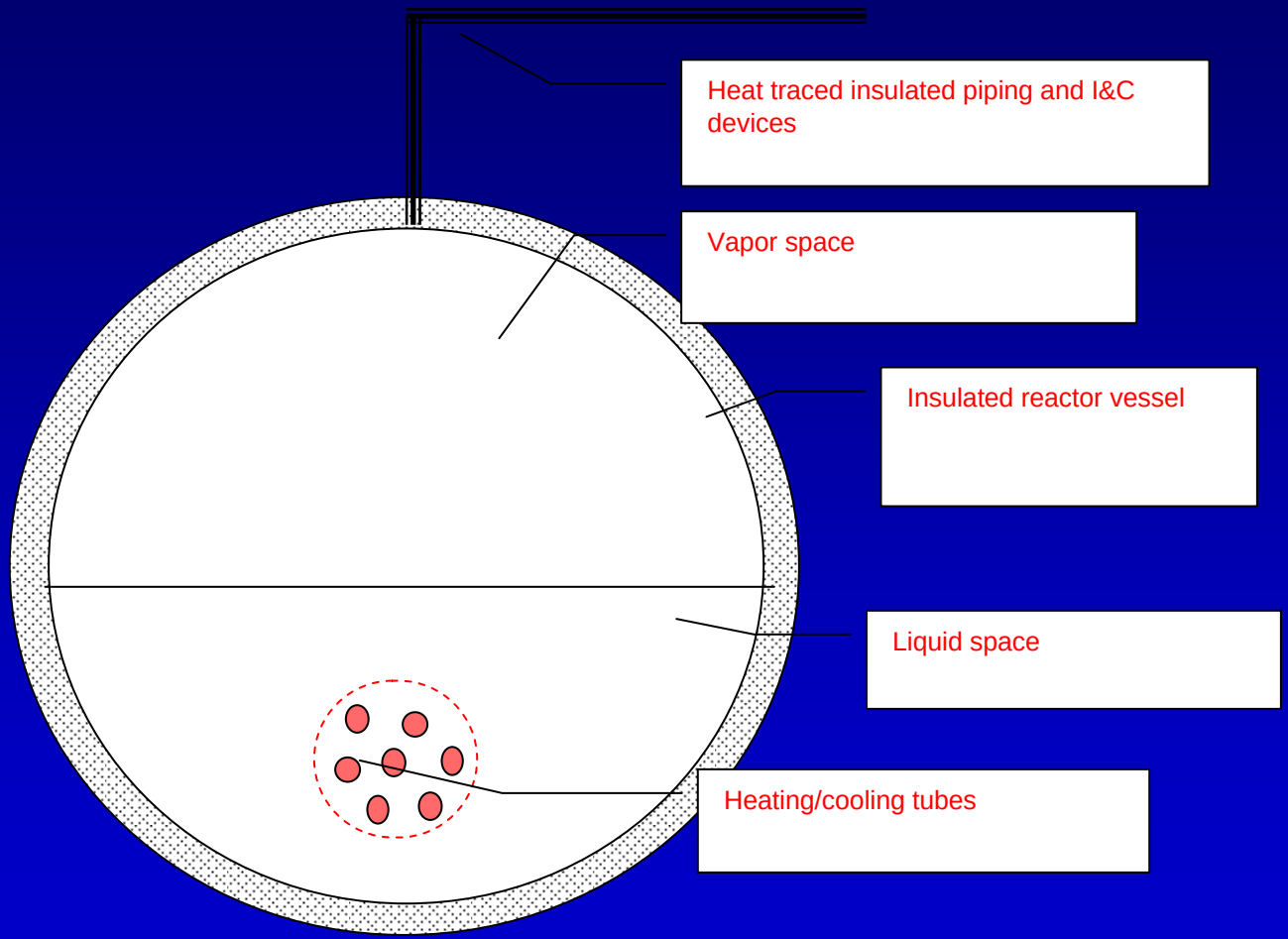
- Process easily follows boiler load variations



Operating Principles

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

Reactor Cross Section



U2A®

3500 lb/hr Hydrolyzer

System Configurations

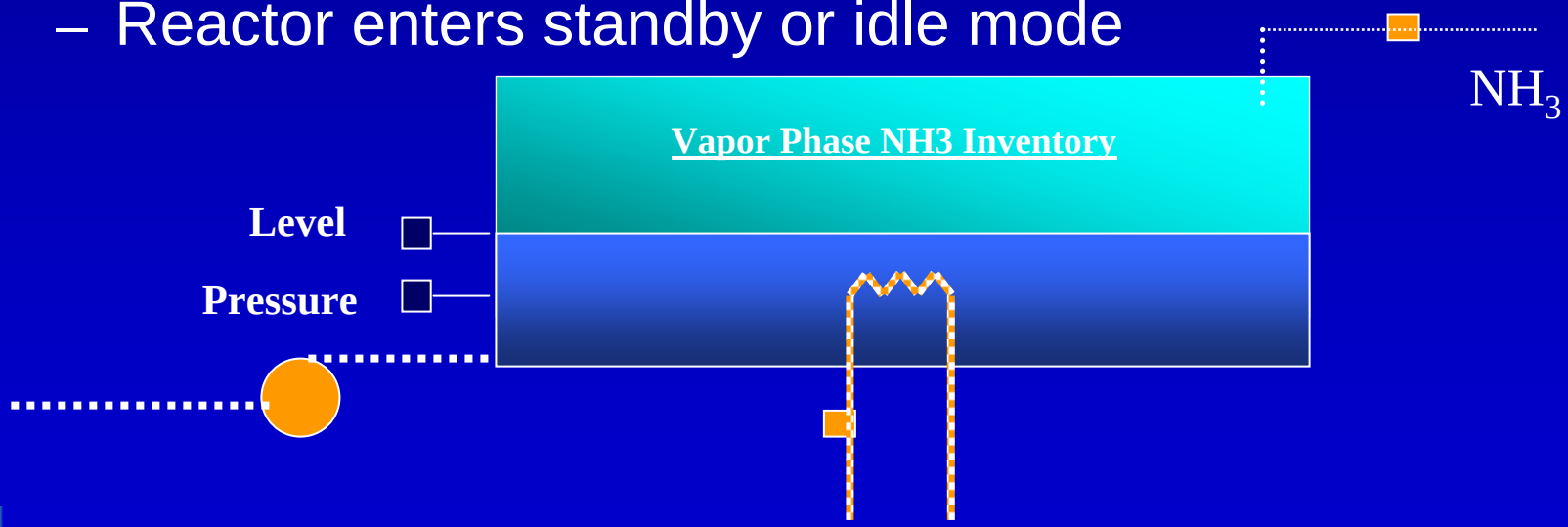
- About Half of Systems have Single Hydrolyzer feed one or Multiple Boilers
- Most Large Coal Fired Applications have 2 X 100% Hydrolyzers
  - Generally we recommend operating both hydrolyzers at reduced rates
  - Instead of one standby and other operating
- Some Large Systems Have 3 X 50% Hydrolyzers

Reliability

- With Redundant Hydrolyzers 99+% Reliability Generally Guaranteed
- Each Hydrolyzer has Redundant Critical Instrumentation
  - Two or Three Radar Level Devices
  - Two to Three Pressure Transmitters
- One Line Blow Down Enables Many Systems to Operate Continuously from Outage to Outage

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



Immediate Shutdown Capability

- Cooling Water (patented feature)
- Automated Blow Back
  - Relief to Urea Feed Tank – interlocked low level
  - Minimal Ammonia Relief
- Manual Relief Valve
  - To Urea Feed Tank
  - Very fast
  - Minimizes ammonia release

System Improvements

- Accurate Radar Level Sensing
- Blow down capability to remove contaminants
- Simplified Control System

Blow Down

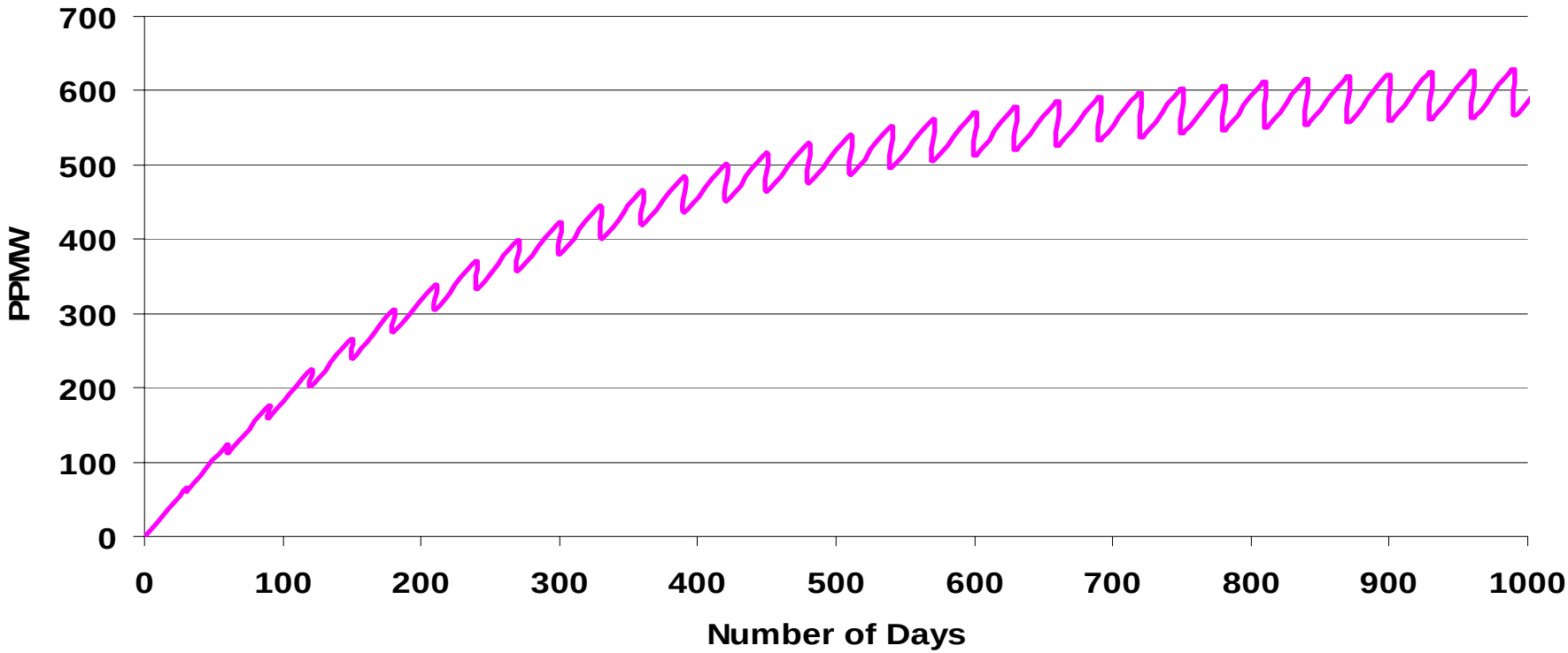
- Urea Impurities Concentrate in Hydrolyzer
  - Metals in urea feed
  - Impurities from DI water
  - Handling / transportation contaminants
- Frequency of Removal
  - Urea Quality
  - Operating Rate
- Periodic Draining of Hydrolyzer

Typical Urea Analysis

- < 0.1 ppm Chlorides
  - Hydrolyzer should be less than 800 ppm
- <0.05 ppm Chrome
  - Generally can be discharged to drain < 5 ppm
- 0.3% Formaldelhyde
  - Most escapes hydrolyzer as vapor and destructed in SCR

Blow Down

- Urea Feed of 1.0 ppm Chlorides
- 10% Blow Down Once Per Month



Differences in U2A

- Simpler Process
- Only two Control Loops – Pressure and Urea Level
- No feed forward signal required for urea flow rate
- No recycle
- No steam stripping
- No economizer
- Lower energy consumption
- No scrubber needed (cooling water & blow back)
- Contaminants controlled with blow down

U2A® Projects (partial list)

– Crystal River	5,892 lb/hr
– AEP Mitchell Station Units 1 & 2	3,500 lb/hr
– Moneypoint Power Station	2,860 lb/hr
– Mirant Morgantown	2,650 lb/hr
– Constellation Brandon Shores Station	2,350 lb/hr
– Hitachi Seminole	2,176 lb/hr
– Allegheny Energy Pleasants Station	1,850 lb/hr
– AEP Conesville Station Unit 4	1,700 lb/hr
– Progress Energy Asheville	820 lb/hr
– Duke Marshall 3	610 lb/hr
– Mid American Council Bluffs	410 lb/hr

U2A® Projects (continued)

– Constellation Wagner Station	460 lb/hr
– AES Huntington Beach Station	380 lb/hr
– City of Spokane	300 lb/hr
– S & W Astoria	250 lb/hr
– AES Alamitos Station	240 lb/hr
– Namjeju Korea	160 lb/hr
– Termokimik AMSA	138 lb/hr
– White Mountain Energy	90 lb/hr
– Termokimik AMSA	33 lb/hr
– IST/(Dominion)/Kauai	28 lb/hr
– Protecma – Reggio Emelia	22 lb/hr
– UCLA	21 lb/hr
– Sinclair Oil	6 lb/hr

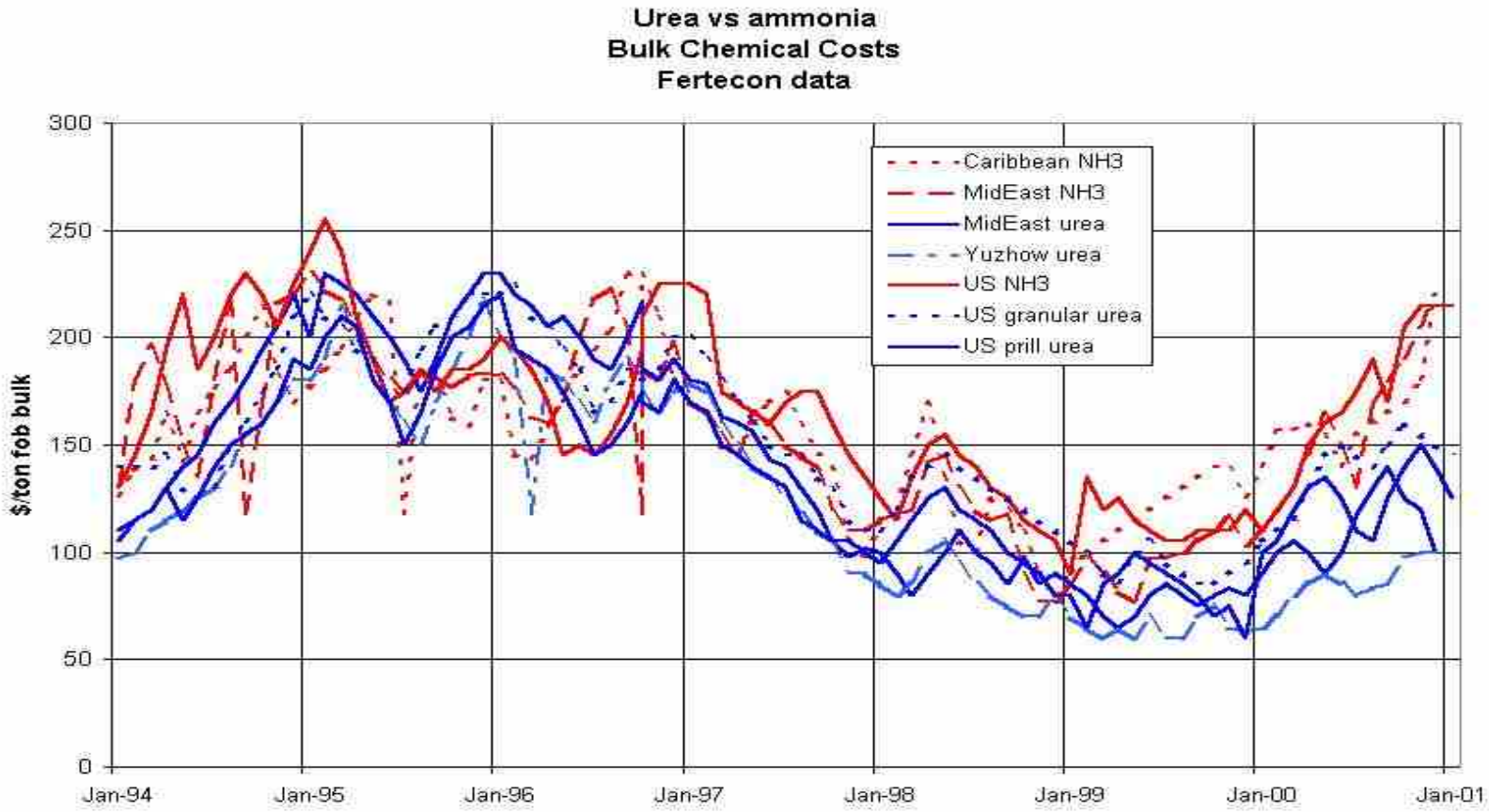
AMMONIA

REAGENT

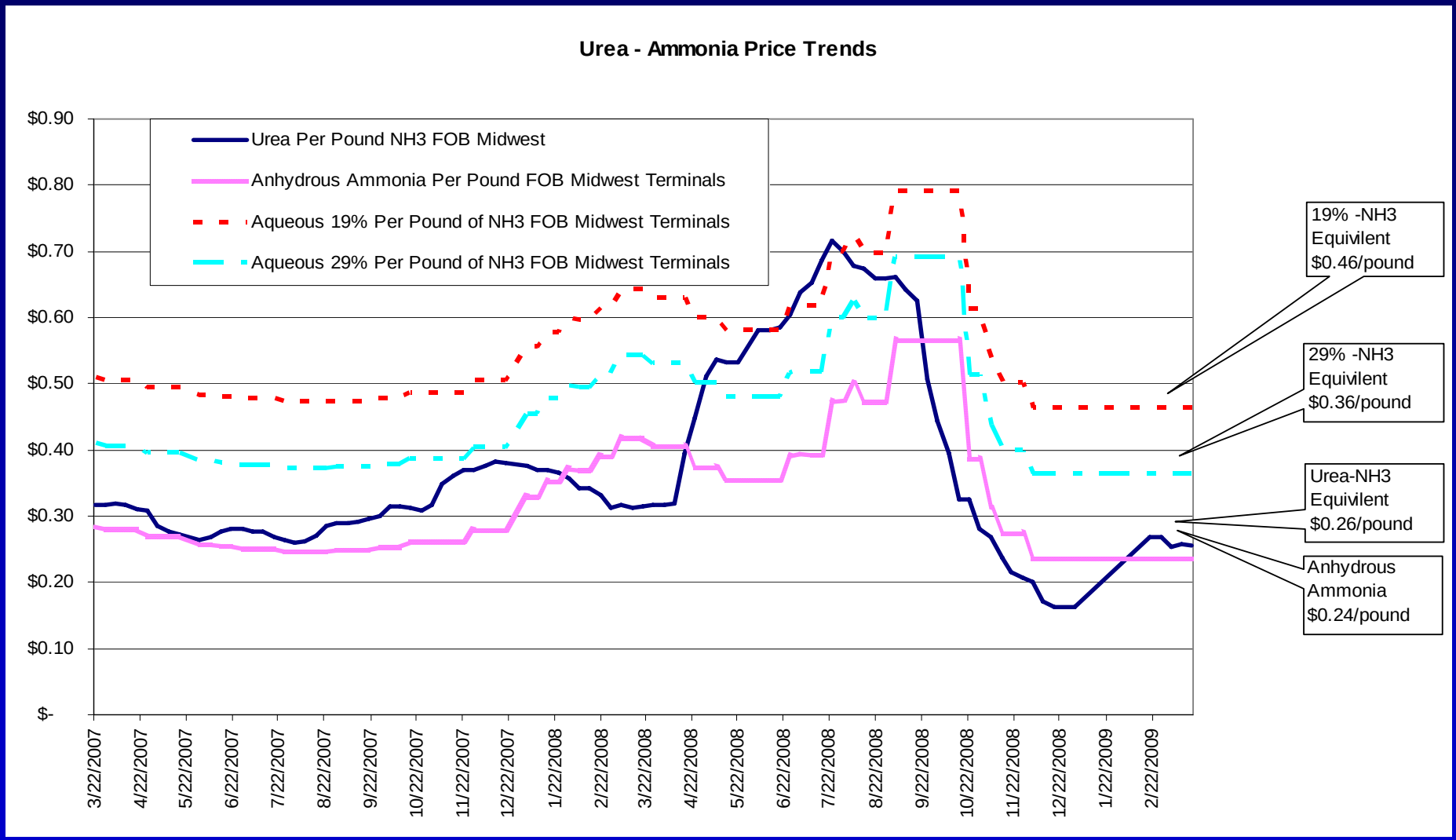
COST COMPARISONS

Urea vs. Ammonia - chemical cost

- Ammonia and urea track with natural gas prices



Urea to Ammonia Price Trends



Recent Ammonia Prices

- Delivered Central Illinois
- Quoted 2/1/10
- NH3 ~ $500 ton ($375 ton Tampa)
- Urea ~ $370 ton ($650 ton NH3)
- 29% Aqueous ~ $230 ton ($788 ton NH3)
- 19% Aqueous ~ $190 ton ($1000 ton NH3)
- Transportation Costs much more for Anhydrous

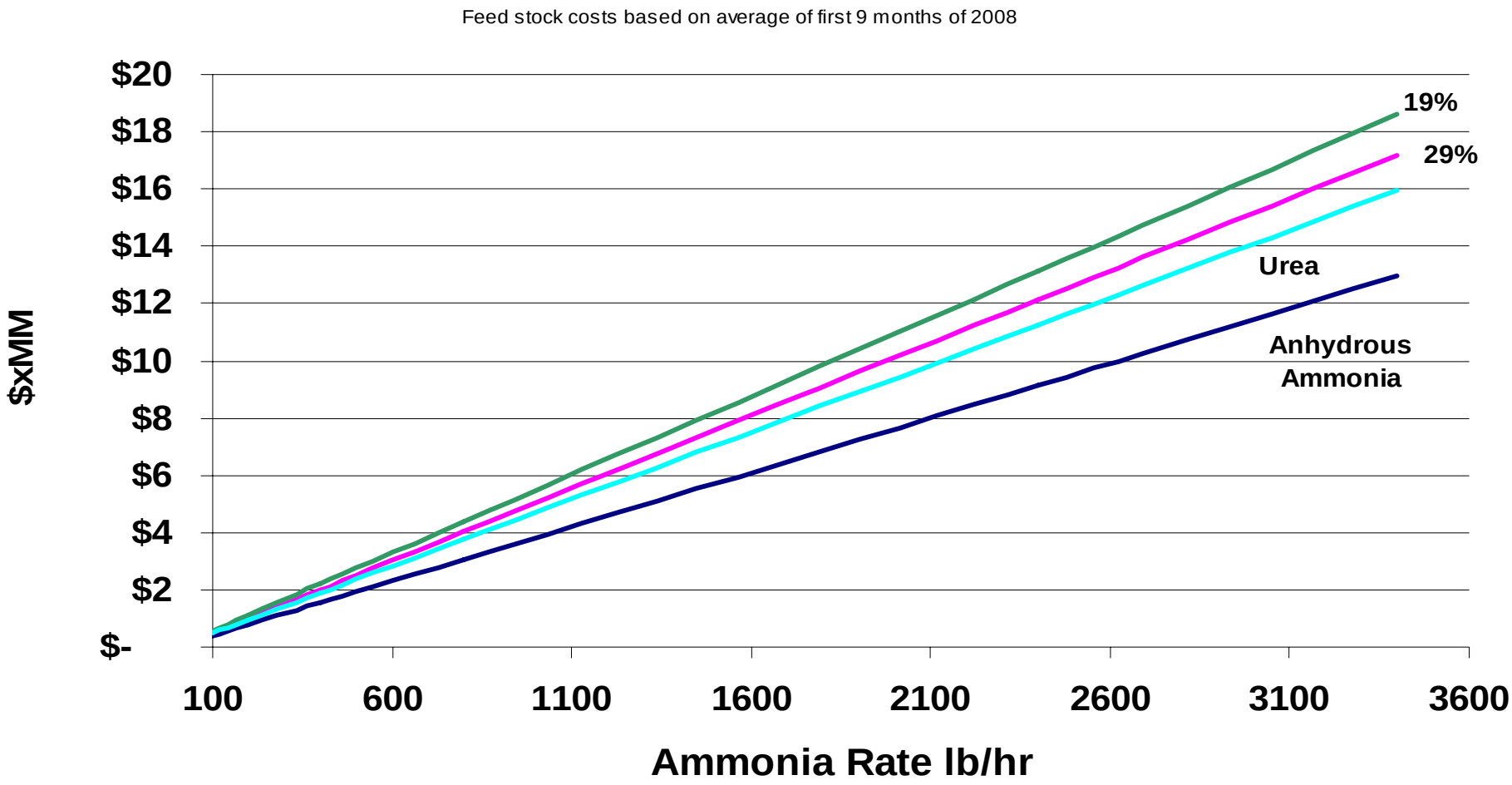
Reagent System Cost Comparison

- Budgetary Costs for Capital Equipment
  - Nominal 3,500 lb per hour ammonia
  - 15 day chemical storage capacity
  - 100% equipment redundancy
  - 2 x 100% Hydrolyzers serving 2 boilers
- Anhydrous Ammonia: $2.5-$2.8 million
- Aqueous Ammonia: $3.2-$3.5 million
- U2A $4.5-$5.5 million

Utility Consumption for SCR Applications

- Anhydrous Ammonia Vaporization
  - 540 btu's per lb of ammonia (0.16 kW)
  - AFCU ~ .32 kW lb NH3
- Aqueous Ammonia (19%) Vaporization
  - 7750 btu's/lb of ammonia (2.3 kW)
  - AFCU ~ .70 kW lb NH3
  - (5.26 lb water / lb ammonia)
- Urea to Ammonia -50% Urea
  - 3354 btu's/lb ammonia (0.98 kW)
  - AFCU ~ .28 kW lb NH3
  - (1.76 lb water / lb ammonia)

Yearly Operating Cost



Feed Stock Comparisons

- Anhydrous
  - Highest Risk
  - Presently the Lowest Capital and Operating Costs
  - Greatest Permitting Issues
  - On Going Safety Training Costs
  - Greatest Uncertainty with Future Regulatory Issues
  - Increasing Transportation Costs

Feed Stock Comparisons

- Aqueous
  - Much Higher Capital and Operating Costs
  - Slightly Less Risk than Anhydrous
  - Huge Storage Volumes and Handling Costs
  - Regulated Toxic Chemical
  - Permitting Issues
  - On Going Safety Training Costs
  - Some Uncertainty with Future Regulatory Issues
  - Increasing Transportation Costs

Feed Stock Comparisons

- Urea
  - Lower Operating Costs than Aqueous Ammonia
  - Lowest Risk
  - No Permitting Issues
  - No Uncertainty with Future Regulatory Issues

Summary

- Urea to Ammonia Systems
  - Safe Alternative to Anhydrous or Aqueous Ammonia
  - Similar Operating Costs to Aqueous Ammonia
  - Non Regulated Feed Stock
  - Less Uncertainty of Future Regulations

Questions