



CHEMITHON

*Ammonia Supply Systems
for SCR*

WPCA/Duke NO_x Seminar

June 7, 2005

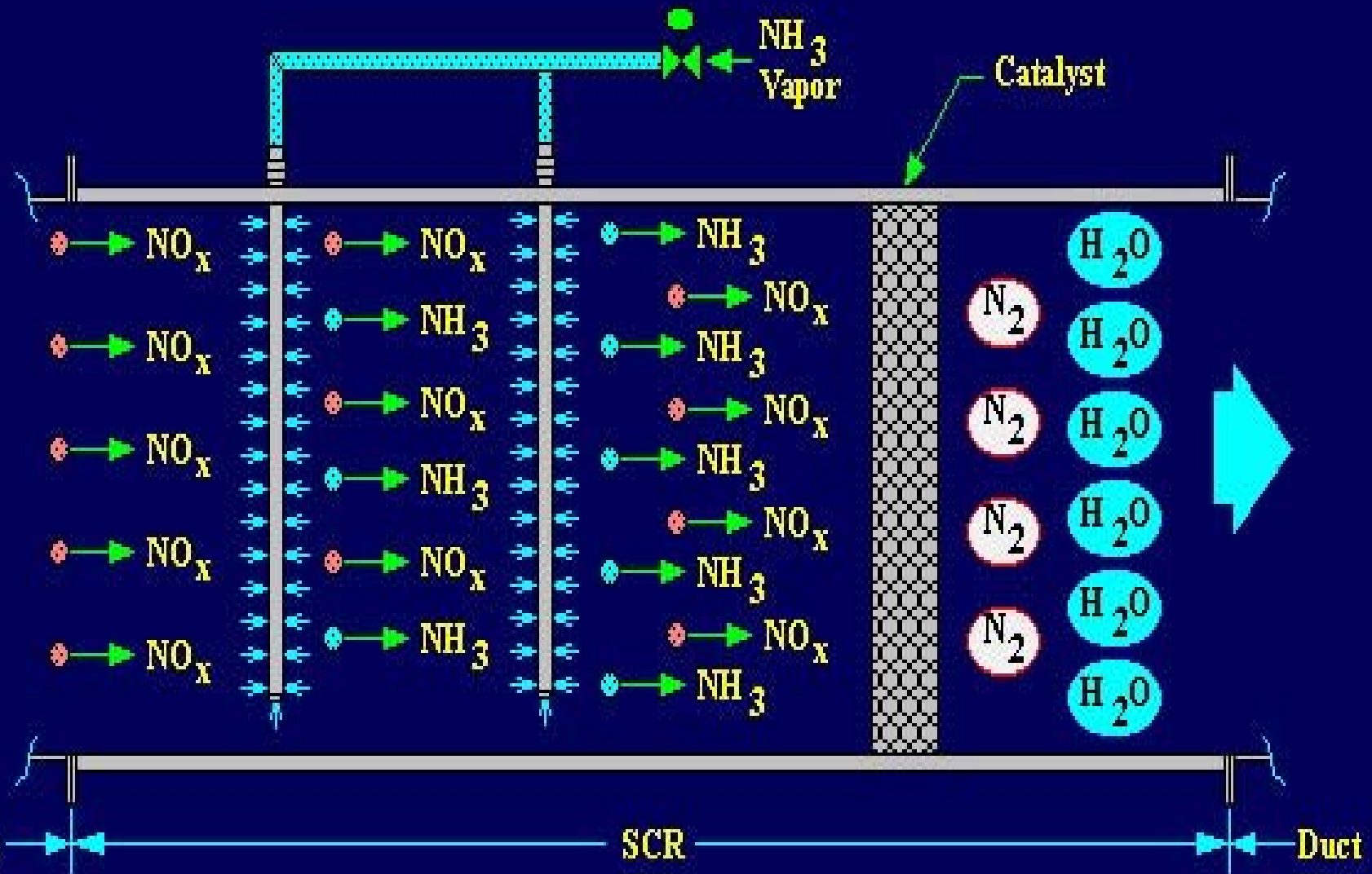
Dr. Norman C. Foster

Why is Ammonia Required?

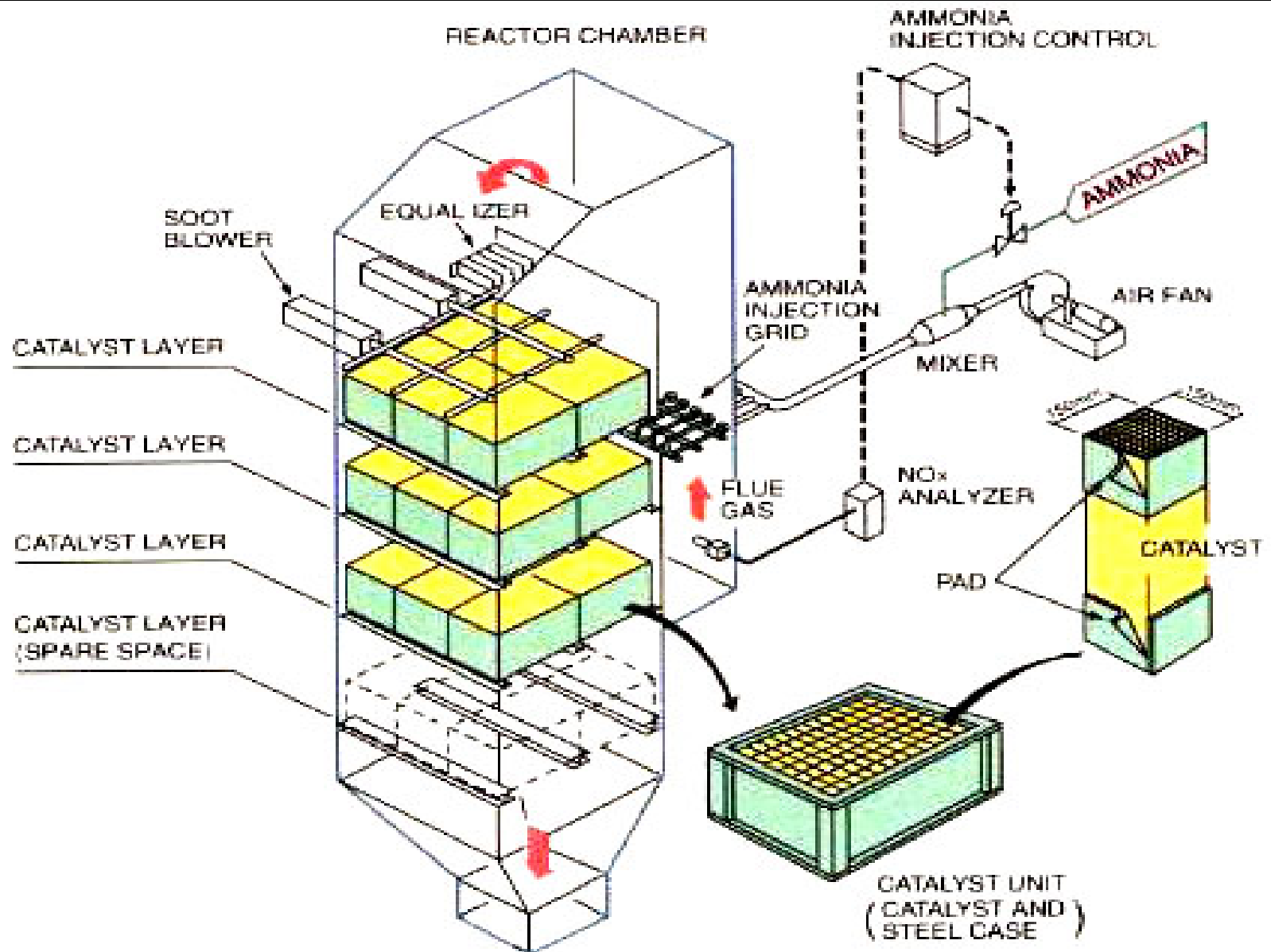
- Ammonia (NH₃) is the Reducing Agent for NO_x
- $2 \text{NH}_3 + 2 \text{NO}_x + \frac{1}{2} \text{O}_2 \longrightarrow 2 \text{N}_2 + 3 \text{H}_2\text{O}$



NO_x Control Using Ammonia



NH₃ Injection System Example



Typical Ammonia Requirements

- **100-5000 lb/h of Ammonia**



Sources of Ammonia

- Anhydrous Ammonia
- Aqueous Ammonia
- Urea



Anhydrous Ammonia Properties

- **Molecular Weight - 17.03**
- **Vapor is 40% lighter than air**
- **Flammable within narrow range 16-25% in air**
- **High heat of vaporization**
 - Used as refrigerant
 - Approximately 588 btu/lb NH₃

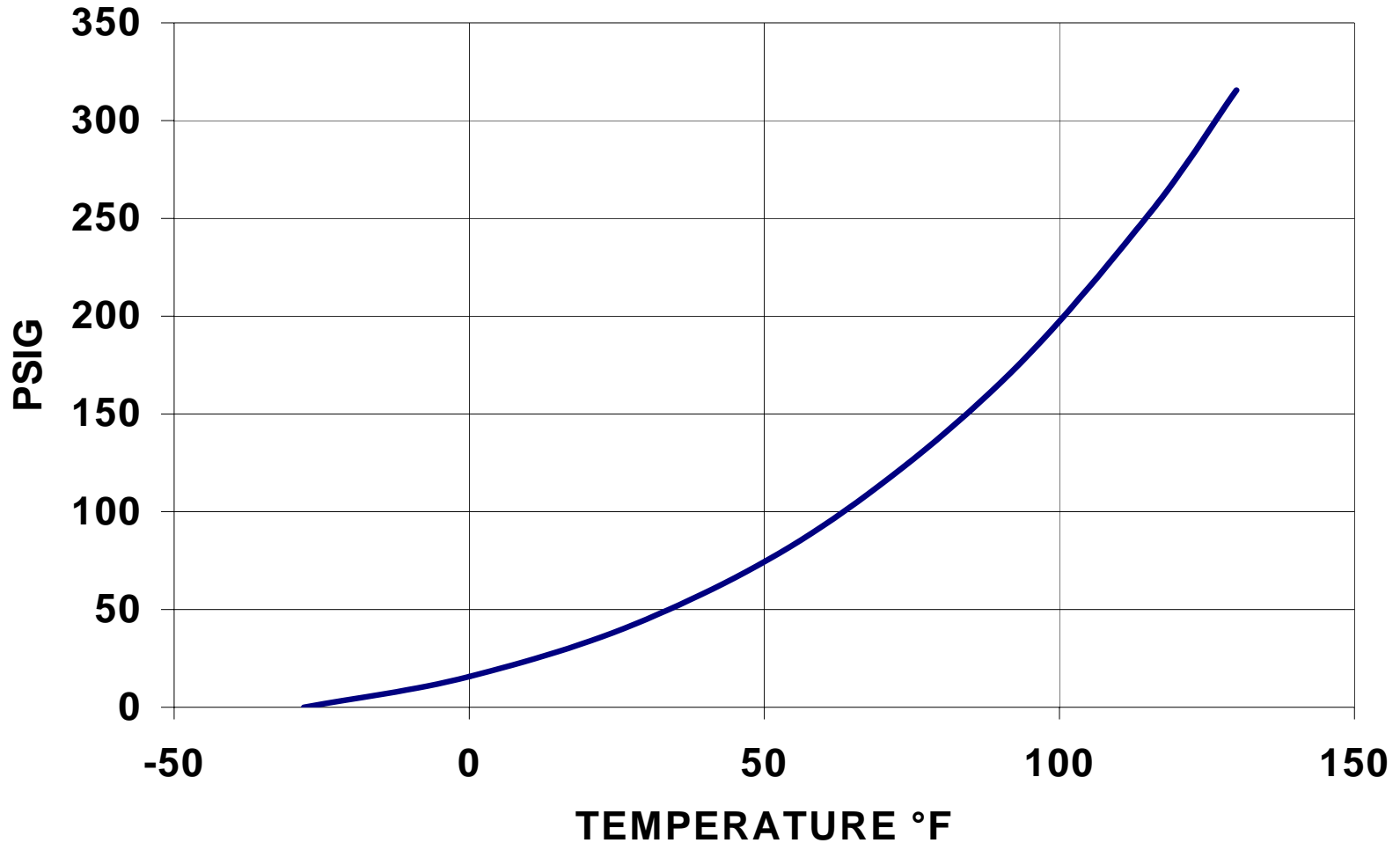


Characteristics of Anhydrous Ammonia

- Liquid when Compressed or Cooled
- Stored as a Liquid under pressure
- 1 Ft³ of Liquid produces 865 Ft³ of 100% pure NH₃ Gas
- 1 Ft³ of Liquid must be diluted with 2,900,000 Ft³ air to reduce concentration below 300 ppm



Anhydrous Ammonia Vapor Pressure



Effect of Pressure

- When liquid anhydrous NH_3 is released from storage pressure it cools
- A drop from 200 psig (100°F) to atmospheric pressure cools ammonia to -28°F .



Anhydrous Ammonia Hazards

- **EPA Regulated Toxic Substance**
 - 40 CFR Parts 9 and 68
- **Requires storage at 250 psig or Refrigeration**
- **OSHA poisonous gas list**
- **Hazards in Transportation and Storage**
- **Single tanker truck spill - 20 acre lethal area**



Anhydrous Ammonia Regulatory Requirements

- **Transport, Handling & Incident Reporting:** 49CFR 171-180
- **Protection of Employees:** 29CFR 1910, OSHA & DOL
- **Incident Reporting:** 49 CFR 1904
- **Environmental Releases:** 40 CFR 1-799, FWPCA 1972, CWA 1977, CWA 1978, TSCA 1976, CERCLA 1980, SARA 1986
- **Emergency Planning and Community Right to Know:** EPCRA 1986
- **Storage Tanks & Vessels:** ANSI K61.1, ASME SEC VIII, Div 1
- **Process Piping:** ANSI B31.3



Ammonia Exposure Limits

Least perceptible odor	5 ppm
Readily detectable odor	20 – 50 ppm
No health impairment for prolonged exposure	50 – 100 ppm
General discomfort; no lasting health effect for short exposure	150-200 ppm
Severe irritation; no lasting health effect for short exposure	400 – 700 ppm
Dangerous less than ½ hour exposure may be fatal	2000- 3000 ppm
Rapidly fatal	5000- 10000 ppm
Immediately fatal	Over – 10000 ppm
From “Anhydrous Ammonia – Pamphlet G-2 Seventh Edition, Compressed Gas Institute	

Uncontrolled Ammonia Releases

- Ammonia Liquid refrigerates and forms lethal fog of Water/NH₃
- Typical Water/NH₃ Cloud is white but may be invisible
- Water/NH₃ Clouds Move Unpredictably with Air Movement
- Water/NH₃ Clouds are heavier than air



Responding to an NH₃ Release

- **Get out of the Area**
- **Notify Emergency Response Staff**
- **Isolate Ammonia Supply**
- **Fog area with water spray**



Anhydrous Ammonia System

**Ammonia
Un-Loading**



**Ammonia
Storage**



**Ammonia
Pumping**

**Ammonia
Vaporization**



**Ammonia
Dilution**



**Ammonia
Injection**

Safety Spray System



Anhydrous Ammonia System Process

- Ammonia is received by Tank Truck
- Unloaded using Unloading Bulkhead and Unloading Compressor System to Storage
- Ammonia is pumped or flows by pressure from storage to the vaporizers
- The operating vaporizer evaporates ammonia
- Ammonia vapor is piped to NH₃ metering/Dilution Air Skids
- Ammonia is metered based on demand from SCR
- Ammonia is metered into air and supplied to the Ammonia Injection Grid just upstream of the SCR.



Anhydrous NH₃ System Unit Operations

- Safety Systems
- N₂ Supply System
- Unloading Bulkhead
- Unloading Compressor System (optional)
- Ammonia Storage Tanks
- Ammonia Pumping System
- Ammonia Vaporizers
- Ammonia Metering and Dilution Air Systems
- Plant / Instrument Air Supply System
- Control System



Anhydrous Ammonia Safety Systems

NH₃ Sensor/Fog Water Areas

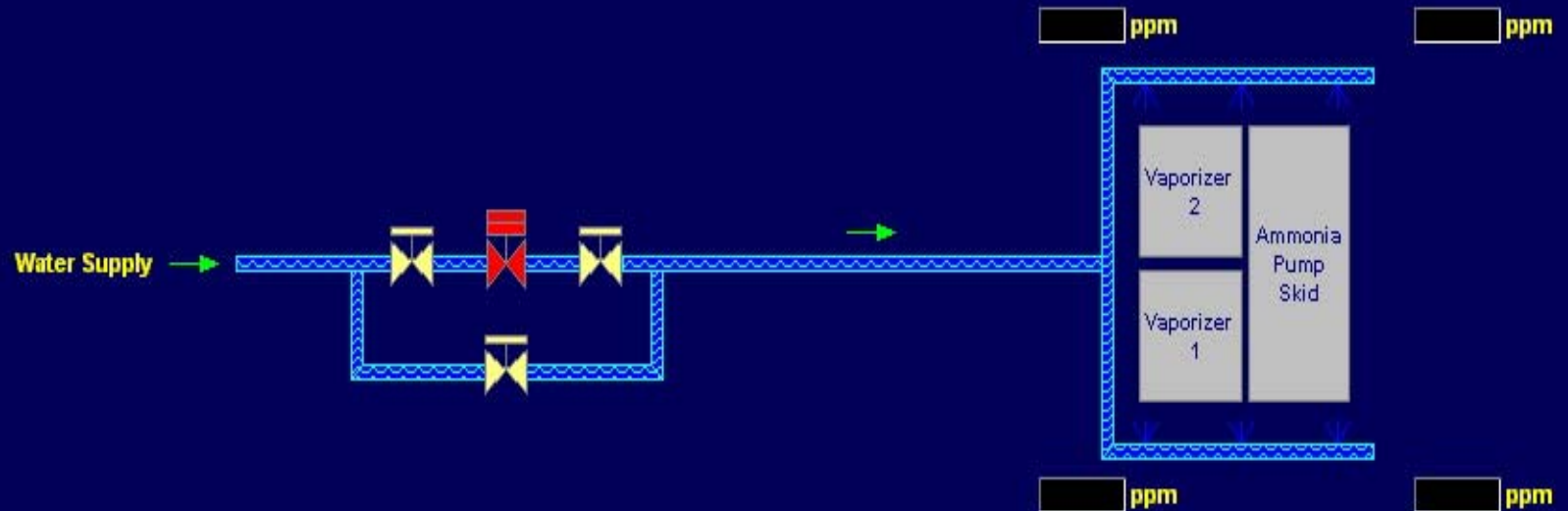
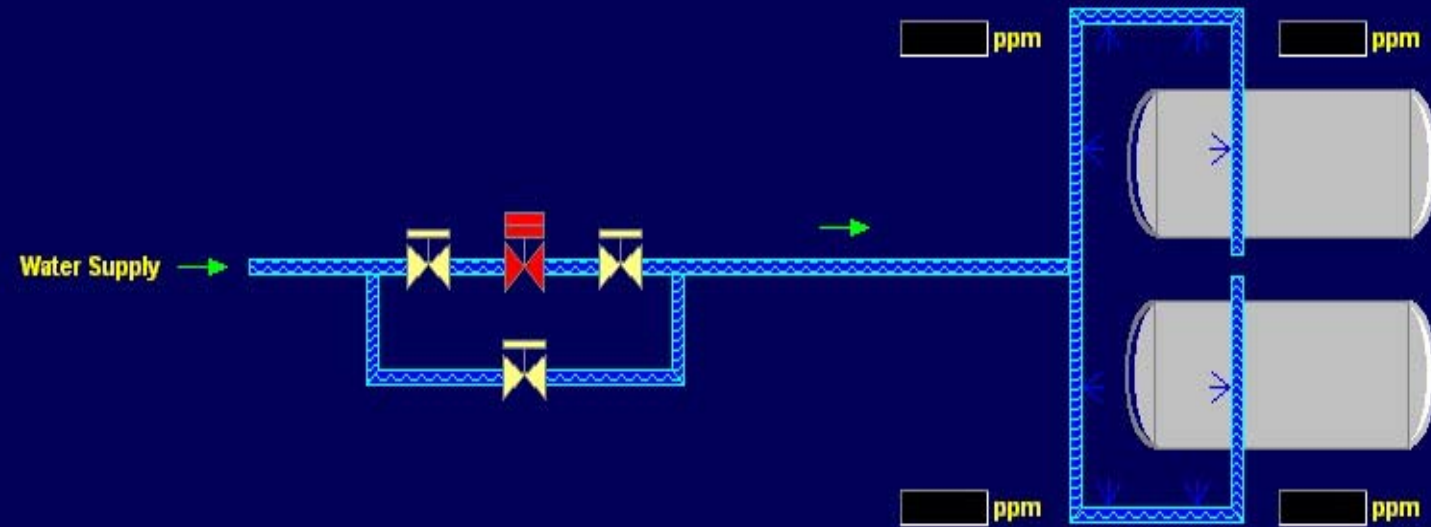
- NH₃ Storage Tank Area
- Equipment Room
- Unloading Area
- Ammonia Metering Dilution Air Skids (3)

Safety Equipment

- Emergency Stops (E-Stops)
- Safety Shower Eyewash Stations
- NH₃ Sensors
- Local Alarm Panels w/ Flashing Beacon & Horn
- Fog Water Systems



Emergency Spray System



Nitrogen Purge System

Why nitrogen (N₂) Purge

- Used to purge unloading arm connections.
- Eliminates NH₃ from connections.
- Eliminates O₂ and H₂O from entering the system.

Equipment

- N₂ cylinder rack
- Pressure reducing valve & pressure relief valve
- Pressure gauge and switch to alarm is low pressure supply.



Ammonia Unloading Bulkhead

- **Equipment**

- **Two Unloading Arms: Vapor & Liquid**
- **Automated liquid line valve, Emergency vapor line valve.**
- **Liquid line flow switch & vapor line pressure transmitter**



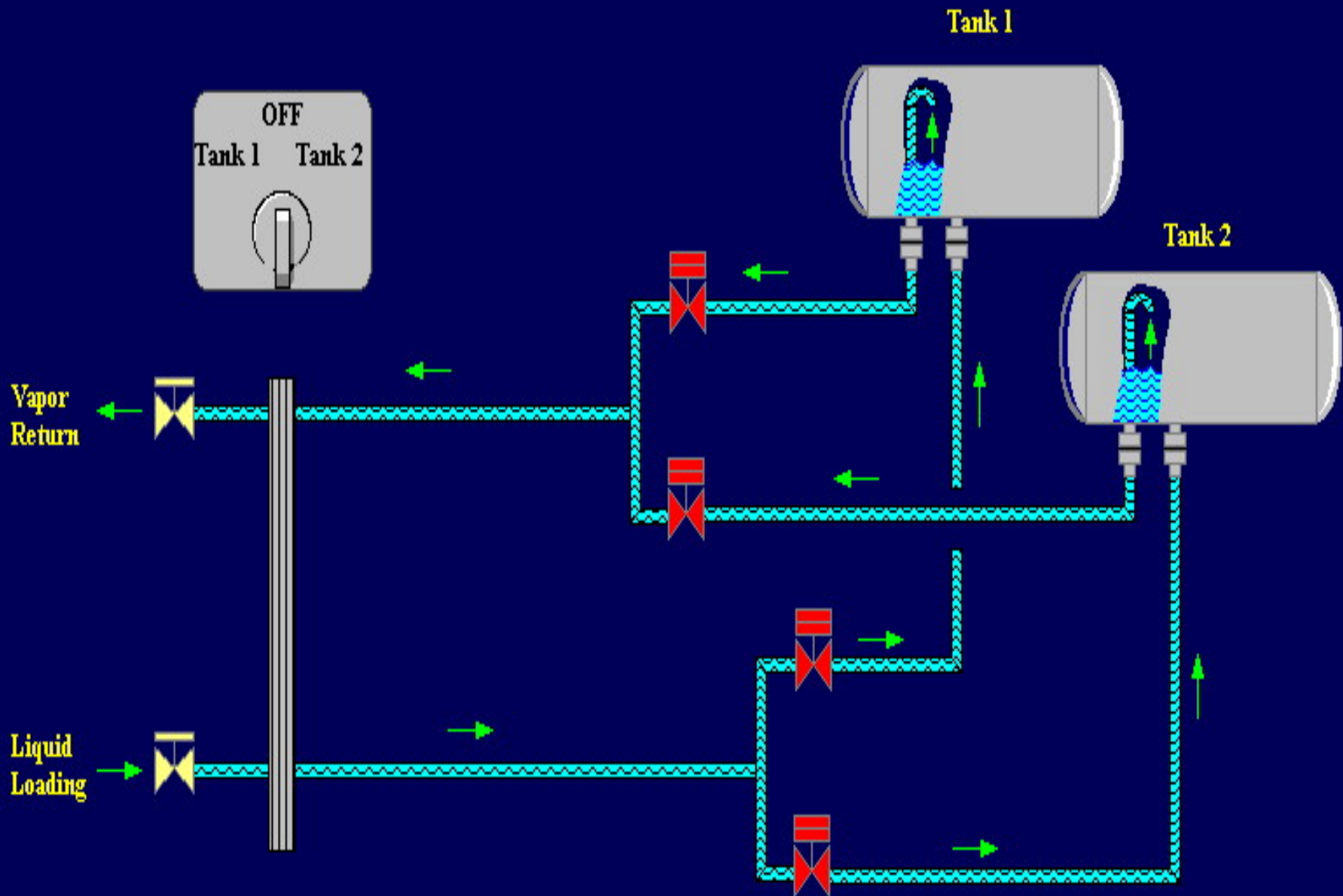
Ammonia Storage Tanks

Equipment

- Ammonia Storage Tanks, Rated 265 to 300 Psig
- Level, Pressure, and Liq. Temperature Transmitters
- Level Switch, Pressure safety valve manifold
- Piping system to select fill and supply tank.



NH₃ Loading and Storage



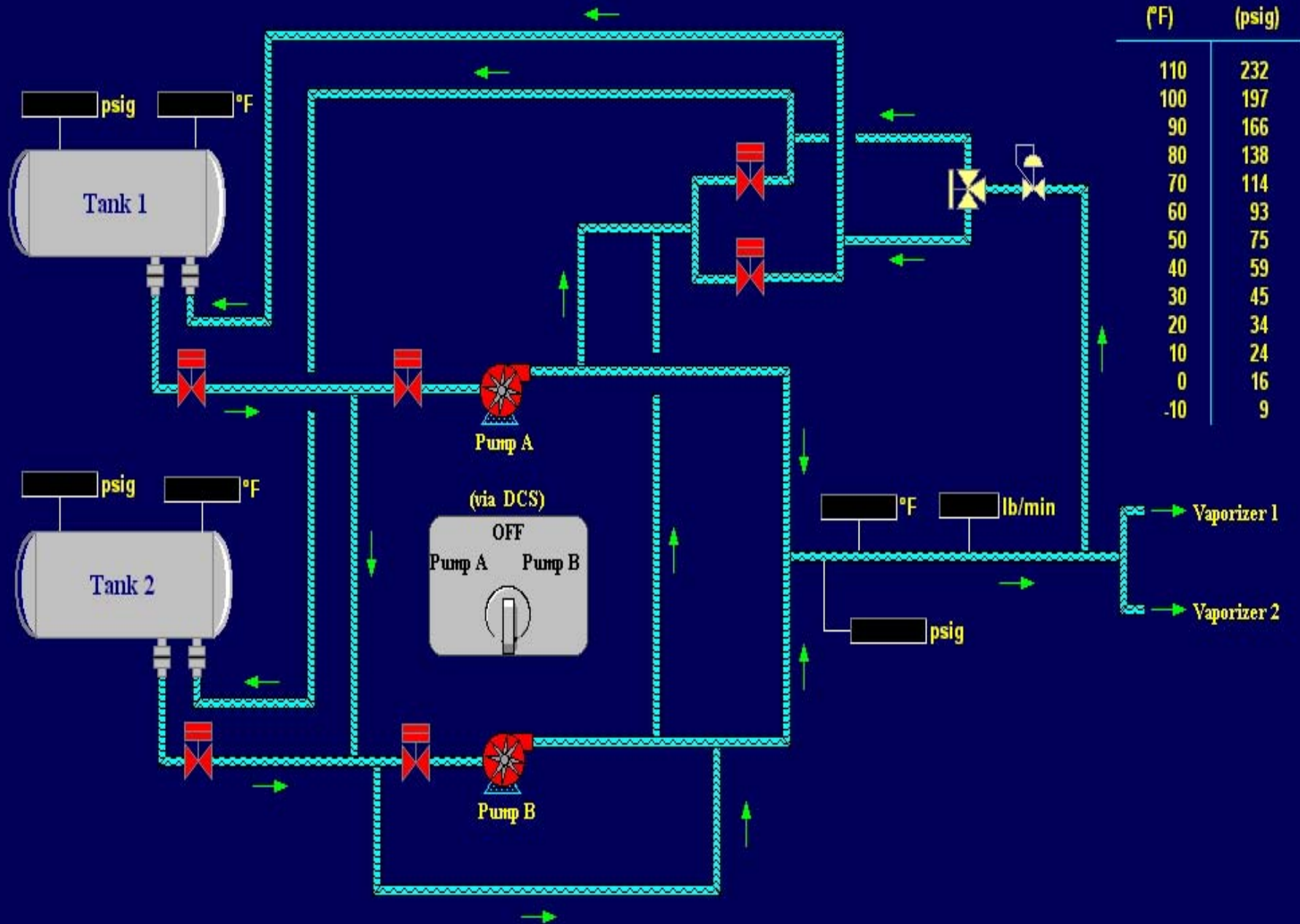
Ammonia Pumping Systems

Equipment

- **Two Side Channel Pumps, one operates, one as inline spare**
- **Pressure Transmitter,**
- **Piping and automatic valves to select supply tank**



NH₃ Pumping



Temperature (°F)	Tank Pressure (psig)
110	232
100	197
90	166
80	138
70	114
60	93
50	75
40	59
30	45
20	34
10	24
0	16
-10	9

Anhydrous Ammonia Tank



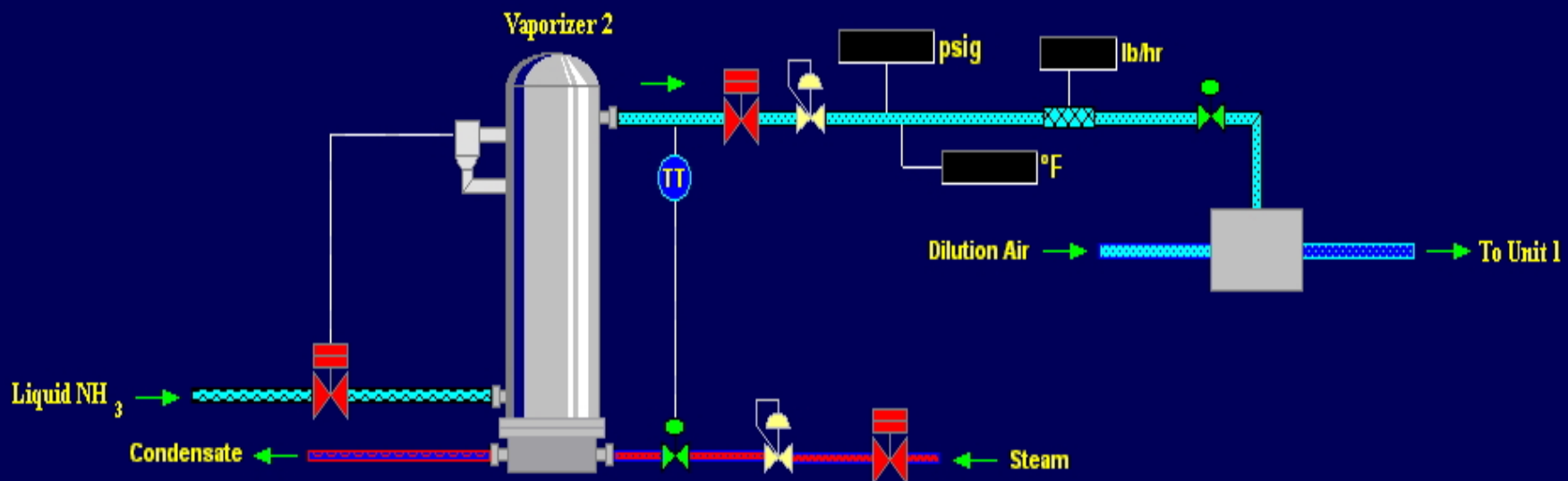
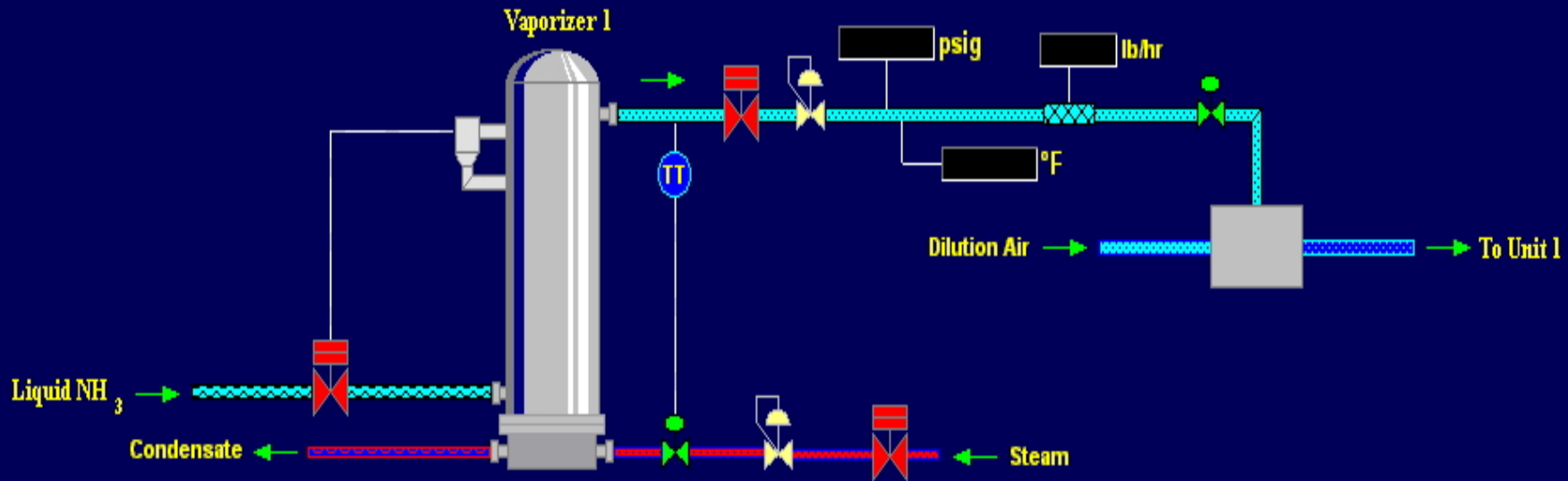
Anhydrous Ammonia Vaporizers

Equipment

- Vaporizers may use either Steam, Electricity or Hot Water
- Two Vaporizers, one operates, one as inline spare
- NH_3 Pressure, NH_3 and Outlet water Temperature Transmitters,
- Piping and automatic valves to select vaporizer



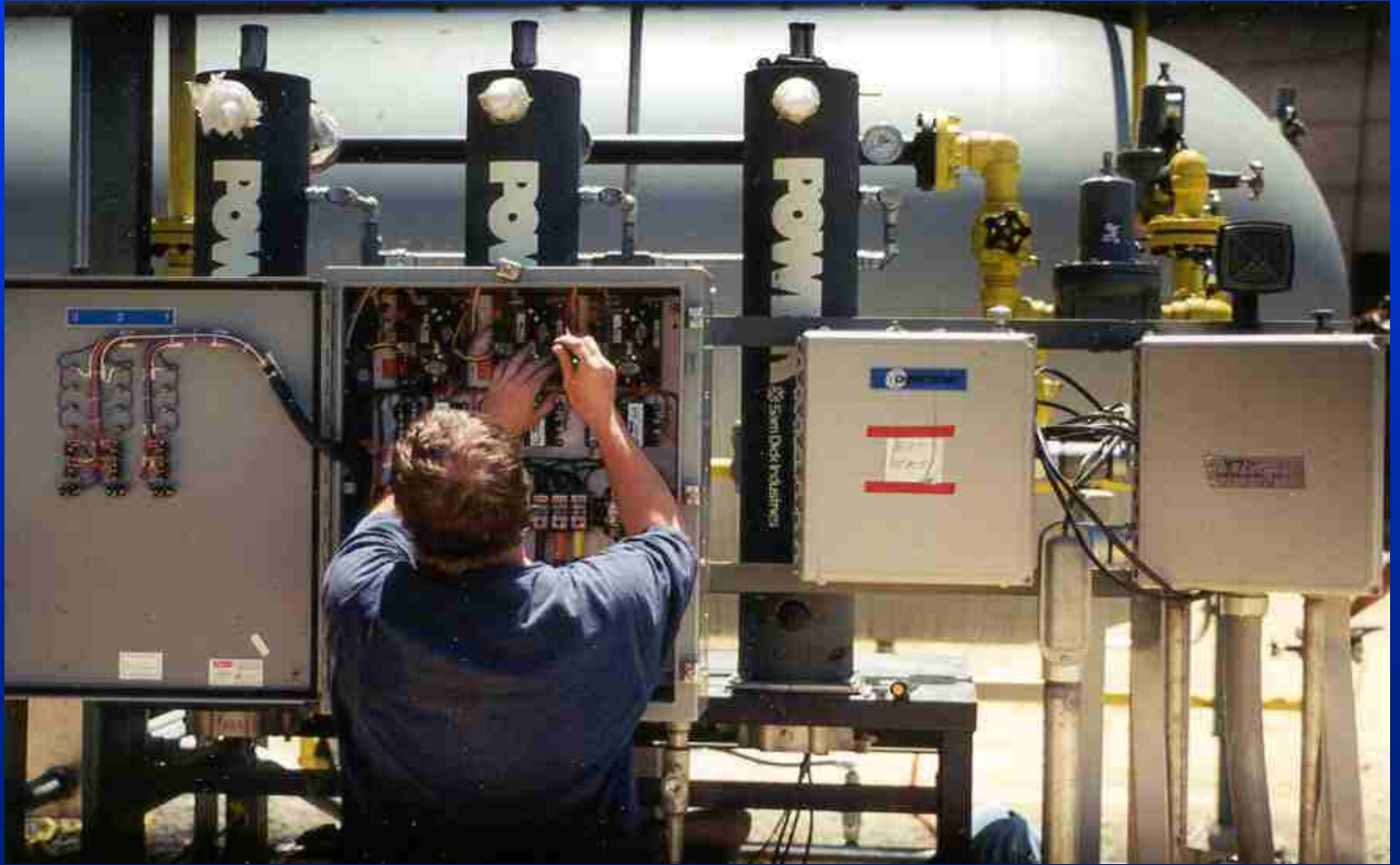
NH₃ Vaporizing



Anhydrous Storage Tank and Vaporizer Skid



Vaporizer Skid Control Panels

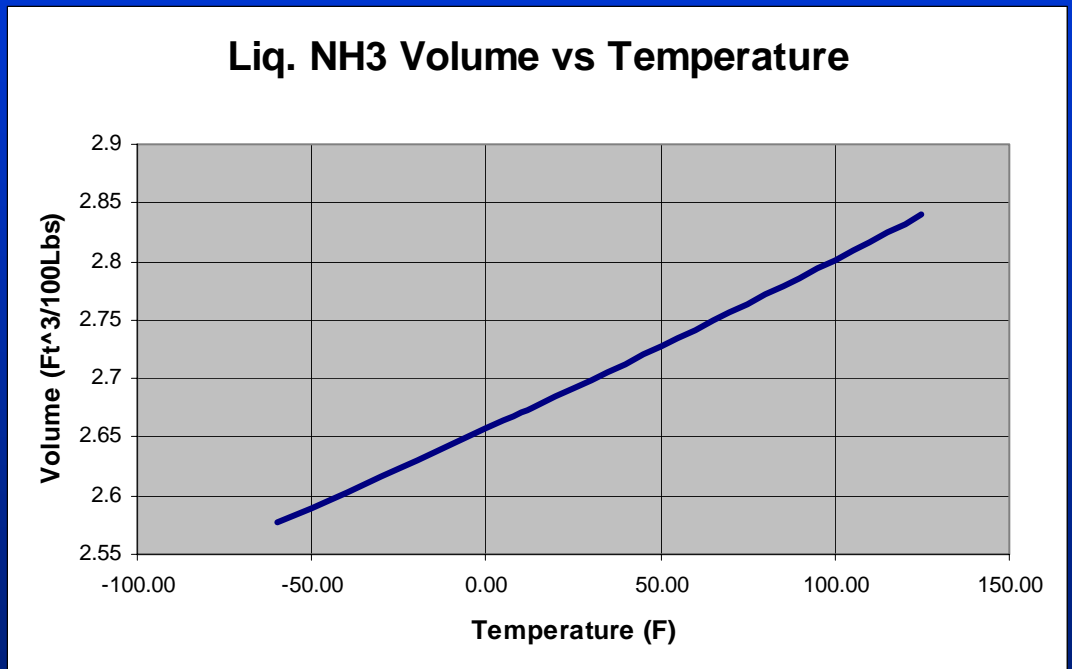


Liquid Ammonia Piping

- Do not block in piping system and components when full of liquid ammonia. Thermal expansion of liquid ammonia will cause extremely high pressures. Ball

valves for
anhydrous
ammonia have
vented balls.

- Hydrostatic relief
valves on
piping system
prevent over
pressurizing.



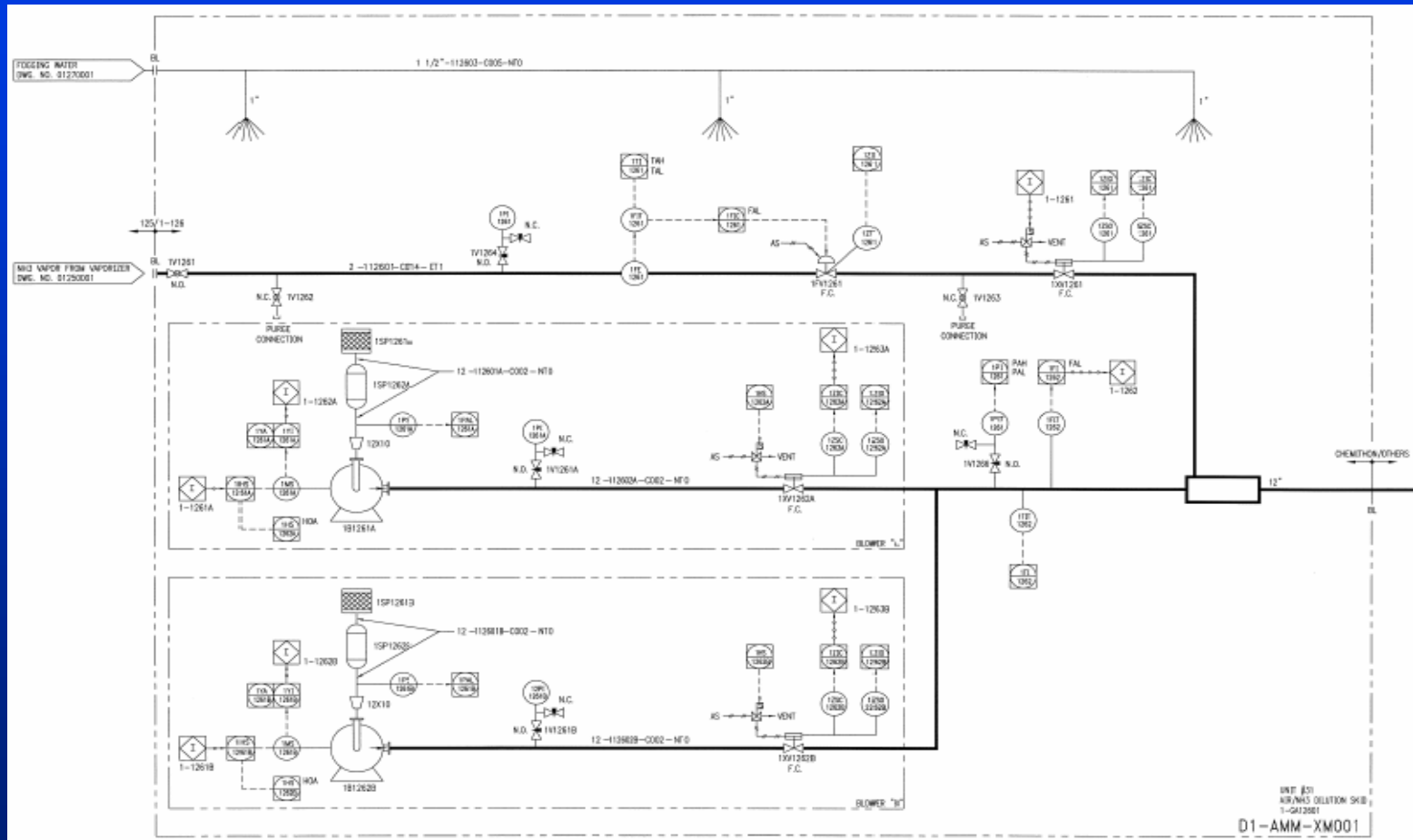
Ammonia Metering & Dilution Air System

Equipment

- Two dilution air blowers, one operates, one as inline spare
- NH₃ and Air: Flow, Pressure & Temperature Transmitters
- Piping and automatic valves to isolate NH₃ vapor and to select the operating blower



Ammonia Metering & Dilution



Dilution Air System



Aqueous Ammonia

- EPA Regulated Toxic Substance
- High energy costs to evaporate water
 - 588 BTU/ lb NH₃
 - 1000 BTU/ lb Water
 - Additional heat required to prevent condensation
- Concentration must be less than 20%
- Transporting and Evaporating water
- Higher Ammonia costs



Aqueous Ammonia System

- **Similar to Anhydrous Ammonia**
- **Lower Pressure Storage Tanks**
- **Fewer Safety Requirements**
- **Uses much more energy to evaporate Water**



Energy Required to Evaporate NH₃

Ammonia Concentration	lbs NH ₃	Lbs Water/ lb NH ₃	BTU/ lb NH ₃
Anhydrous NH ₃	1	0	588
28% NH ₃	1	2.57	3,159
19.5% NH ₃	1	4.13	4,716



Aqueous Ammonia Storage Vessel



Pump Skid

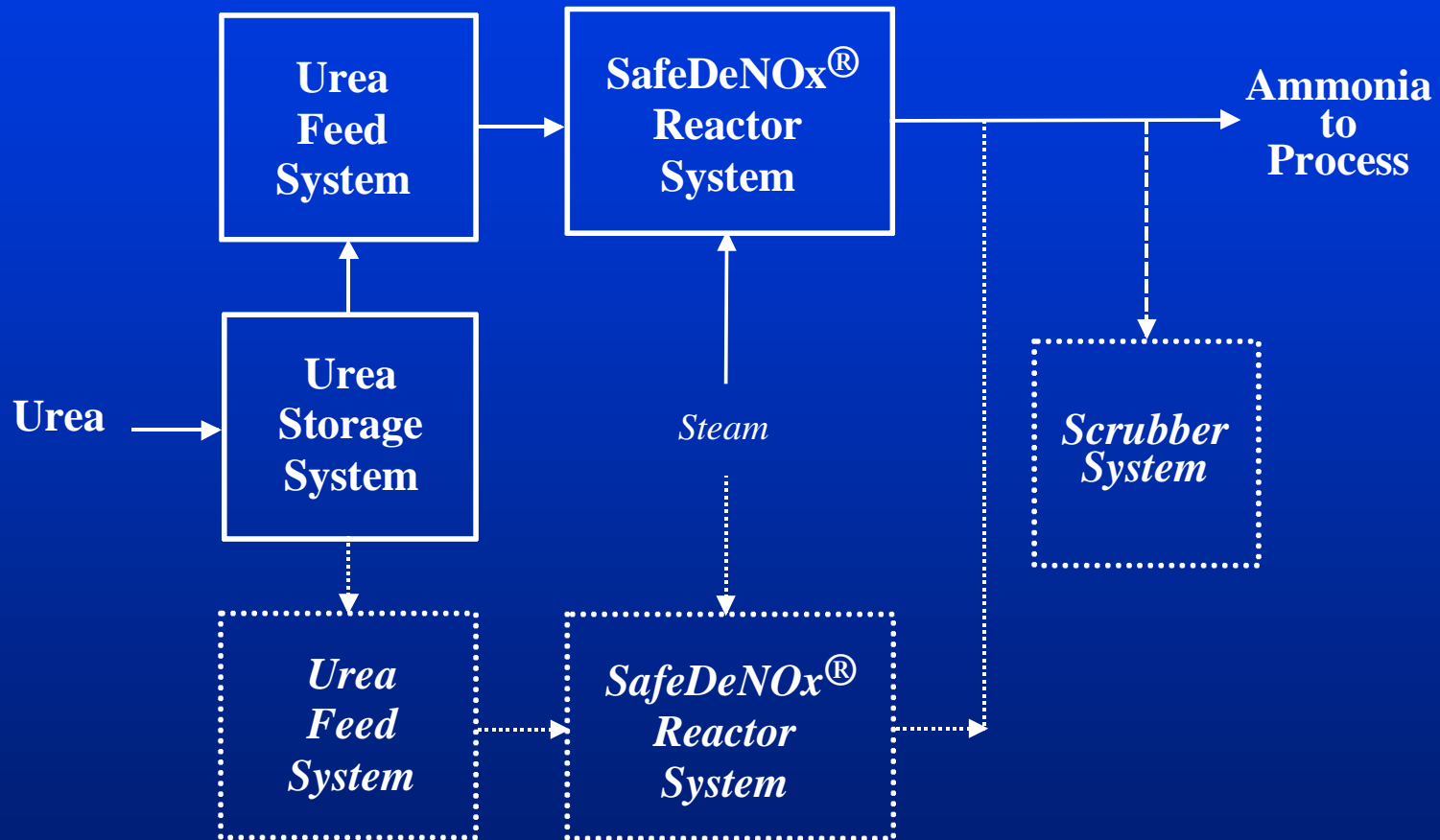


Urea

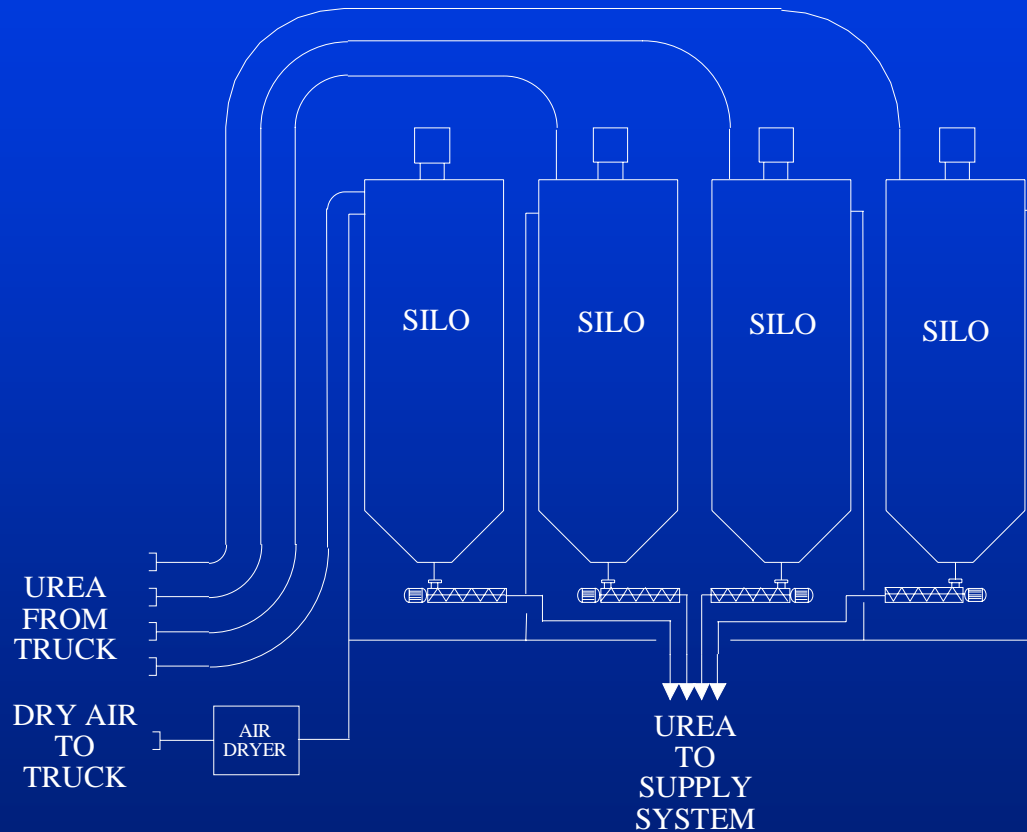
- Safe non toxic stable material
- Primary active component in fertilizer
- Readily available
- Delivered costs per pound of ammonia less than aqueous ammonia
- Typical delivered costs about 1.5 to 2 times anhydrous per pound of ammonia



Chemithon SafeDeNOx[®] Urea-to-Ammonia Process



Dry Urea Storage & Unloading



Dry Urea Storage

- **Truck can deliver up to 35 tons per load**
- **Rail can deliver up to 100 tons per load**
- **1,100 pounds of ammonia per ton of urea**
- **Most economical form to store urea**

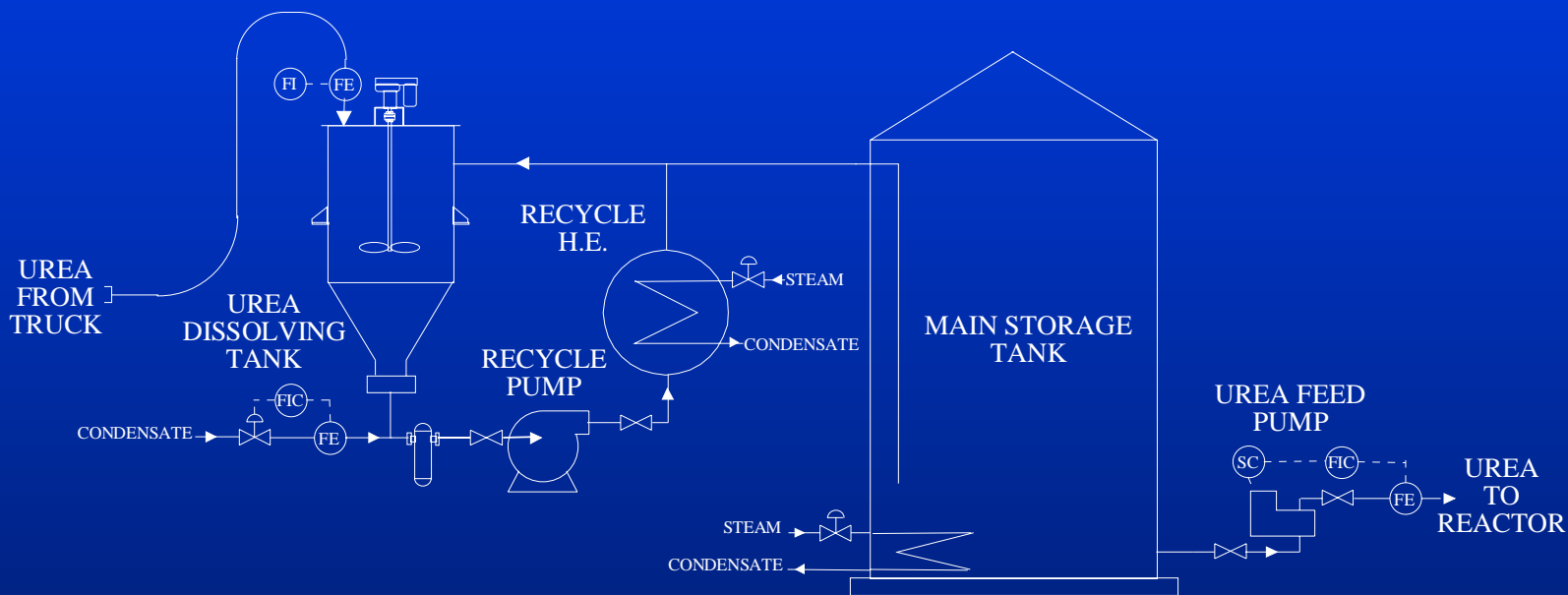


Dry Urea Storage Benefits

- **Lower operating cost - no heated tanks**
- **Lower delivered cost**
- **No spill containment required**



Batch Urea Dissolving & Storage

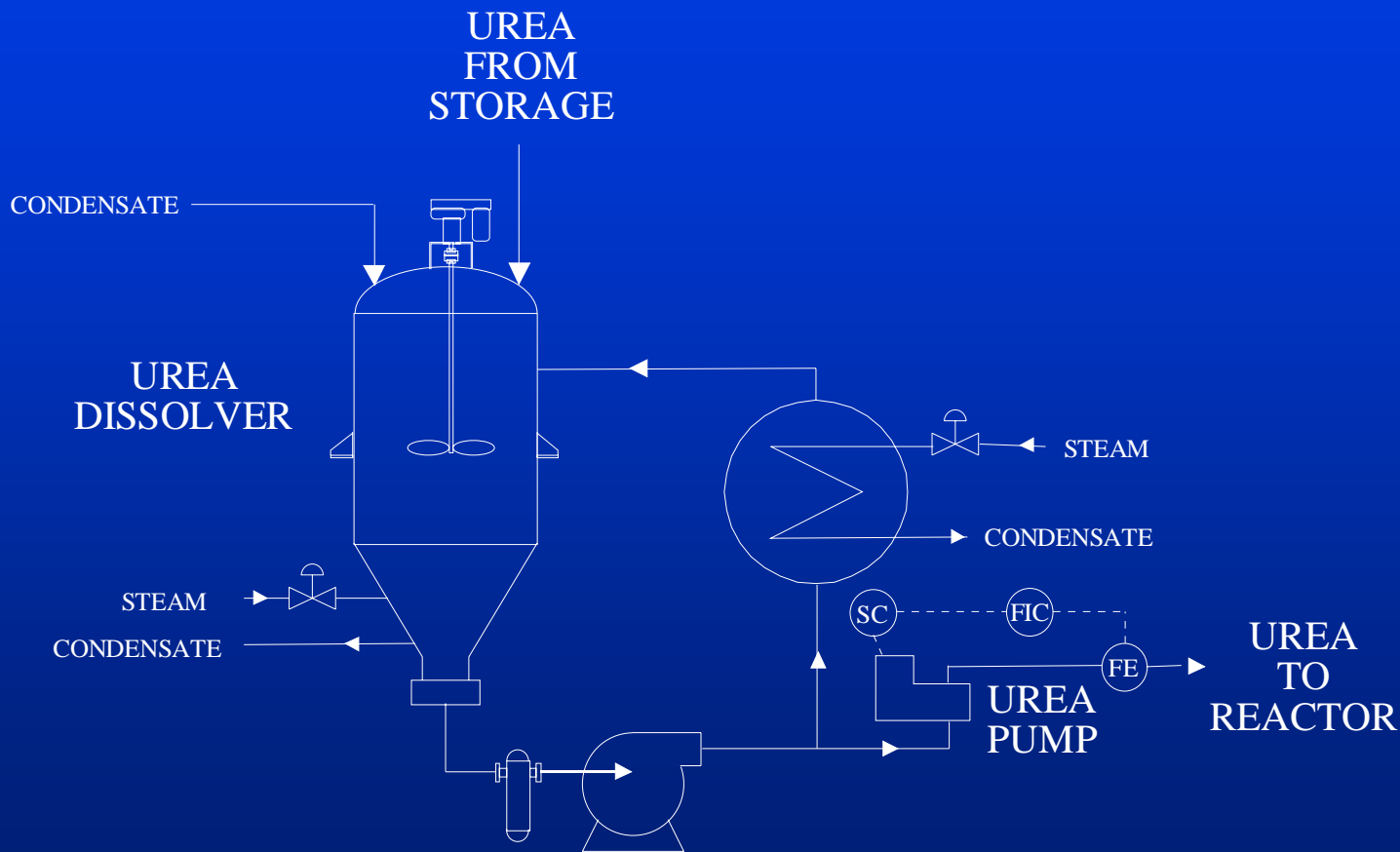


Continuous Urea Dissolving Step

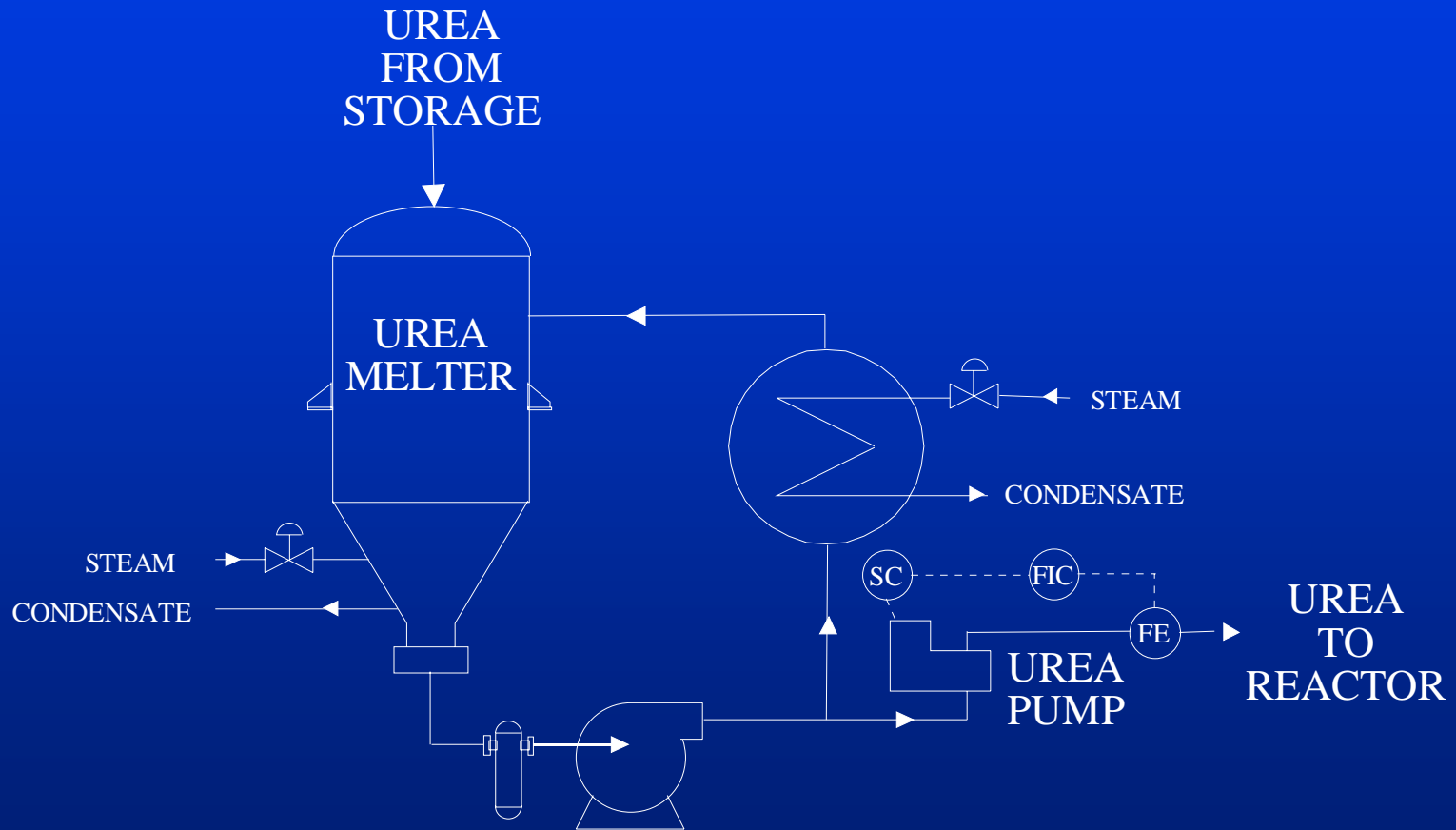
- Can be continuous or batch
- Requires density control
- Mixing tanks are needed
- Requires DI water service and storage
- Best choice for smaller systems



Continuous Urea Dissolving System



Urea Melter System

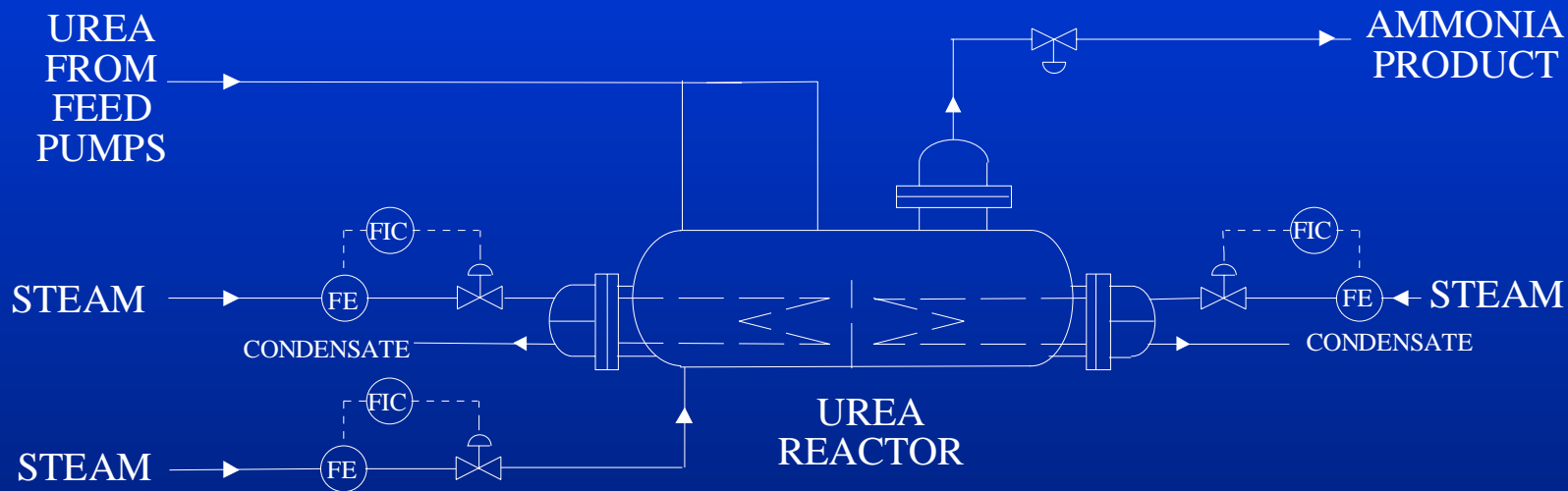


Urea Melter System

- No de-ionized water needed
- Urea melts at 271°F (133°C)
- Molten urea has a low viscosity and is easily pumped
- Similar to sulfur
 - Chemithon has over 40 years of experience in melting and handling sulfur

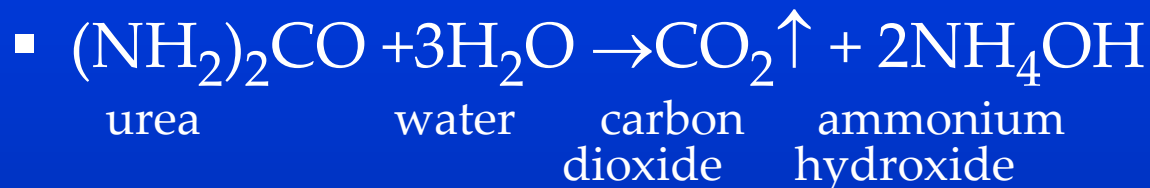


SafeDeNOx[®] Reactor System



SafeDeNOx[®] Process Reactions

■ Urea Decomposition



■ Neutralization of MAP



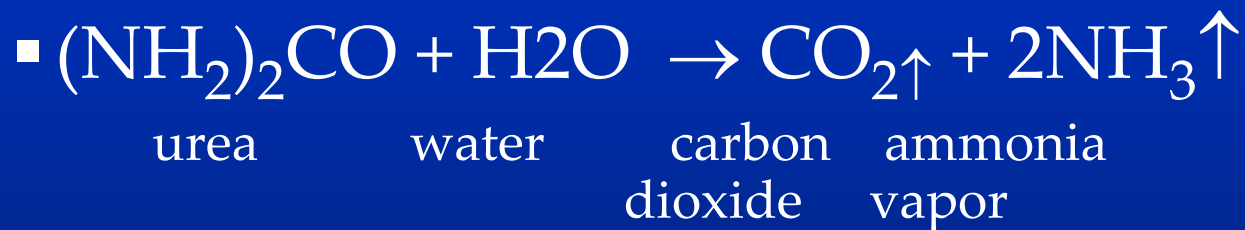
■ Decomposition of DAP



SafeDeNOx[®] Overall Reaction

- At equilibrium all three reactions occur simultaneously

- Overall reaction



SafeDeNOx[®] Catalyst Information

- **Mixture of Mono Ammonia di-hydrogen Phosphate (MAP) and Di-Ammonia hydrogen Phosphate (DAP) (excess)**
- **It is a white, water-soluble crystal, easy to add through the feed system.**
- **3,300 lbs (1,500 kg) of catalyst for 1,400 lb/hr (635 kg/hr) reactor**

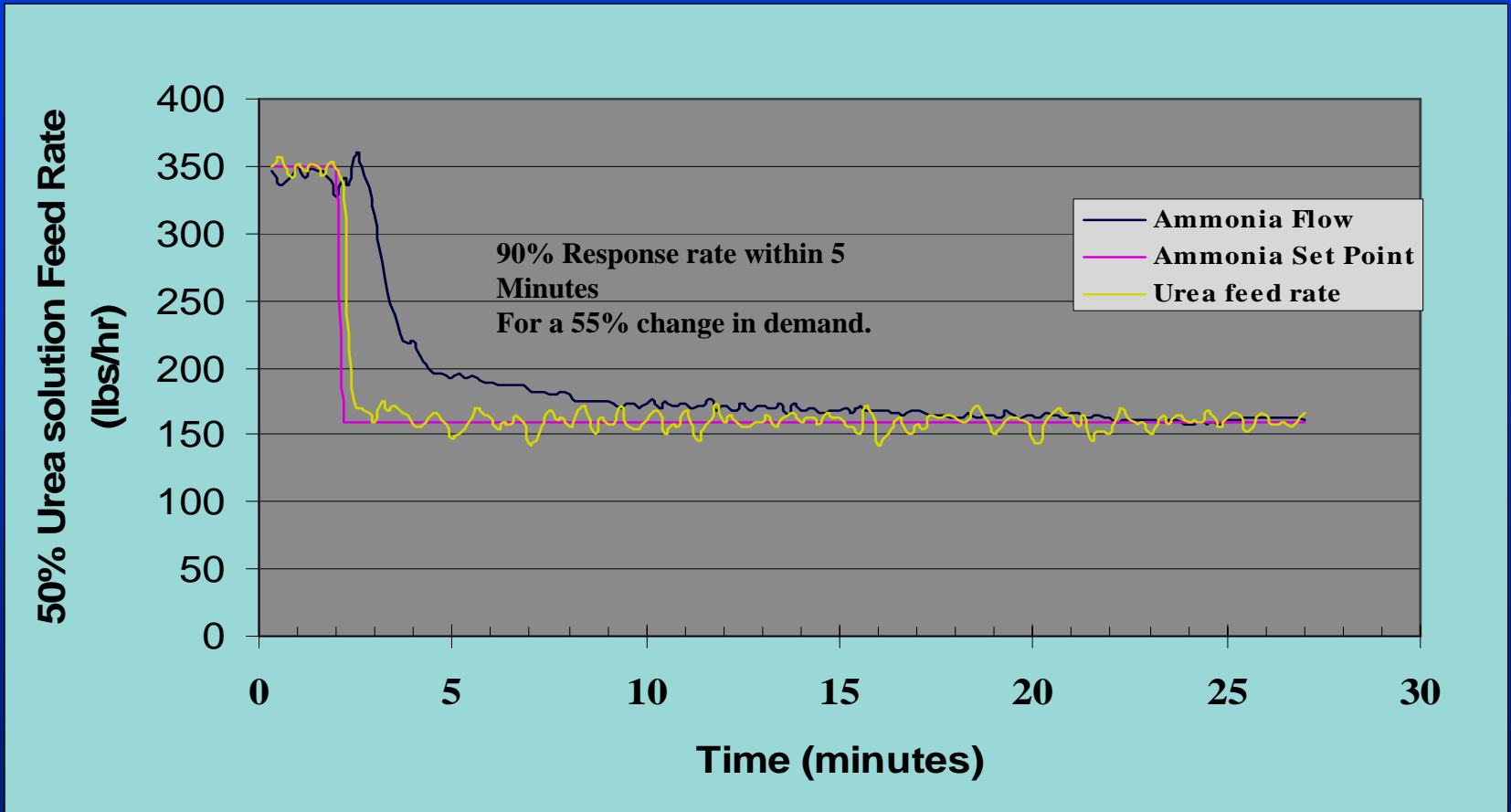


SafeDeNOx[®] Reactor System

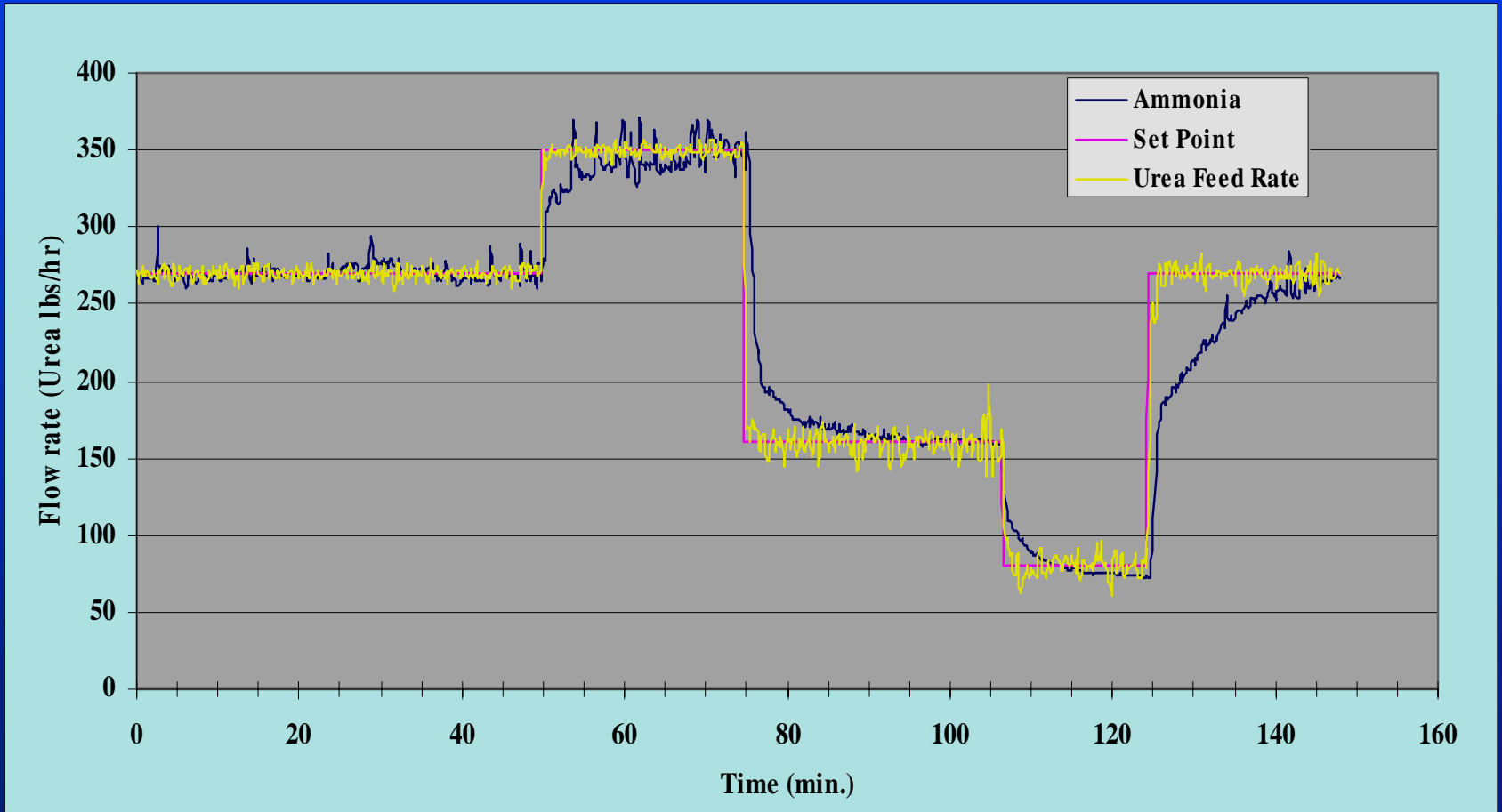
- **Uses self-regenerating catalyst to accelerate the reaction**
 - Mono-ammonium phosphate (MAP)
- **Catalyst allows near stoichiometric levels**
 - minimizes energy requirements
 - Approximately 3,500 BTU's/lb (1,945 kcal/kg)
 NH_3



SafeDeNOx[®] Response Rate



SafeDeNOx[®] Response Rate



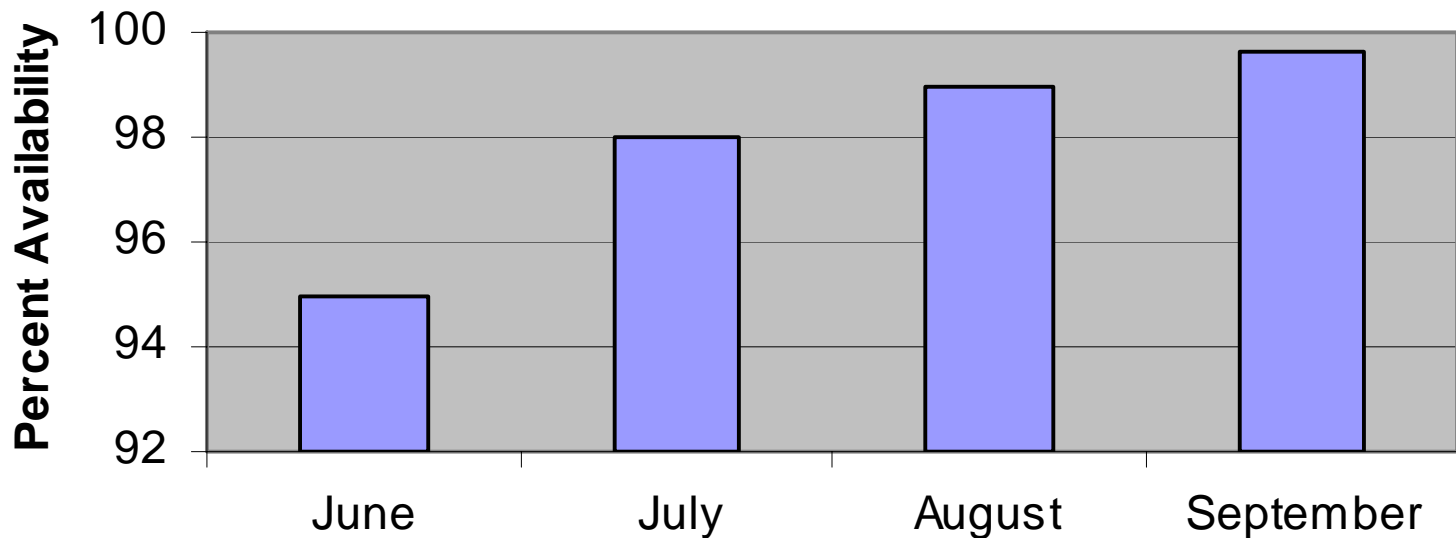
SafeDeNOx[®] Benefits

- Responds quickly to changes in ammonia demand
- Self-regenerating catalyst significantly reduces urea residence time
- Constant ammonia concentration (minimizes slip)



Startup of First Commercial System Reliability - 98% Average

Plant Karn 1 & 2 Availability



800 lb/hr (360 kg/hr) SafeDeNOx[®] System



Urea Storage and Handling



Urea Feeders & Melter



Thank you

Questions

