

Design & Operation of U_2A^{TM} Building on Experience



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U₂ATM Background

- ◆ **U₂ATM** (urea to ammonia) is a patented system to meet ammonia needs with reduced risks
 - ❖ Highest ammonia risks:
 - Shipping
 - transfer
 - storage
 - ❖ Urea is a benign material
 - Safely transported, transferred and stored
 - Readily available as bulk commodity chemical
 - Urea is 56% ammonia (equivalent)
 - Economical alternative to aqueous ammonia

U₂ATM



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U₂A™ Background

□ EC&C, Wahlco and Hamon Research-Cottrell

- ◆ EC&C (Dr. Spencer, Dr. Cooper) licensors
 - ❖ Strong technical support
 - ❖ U.S. patents 6,077,491; 6,322,762

- ◆ HRC/Wahlco Alliance
 - ❖ Offices on both coasts
 - ❖ Flexible execution



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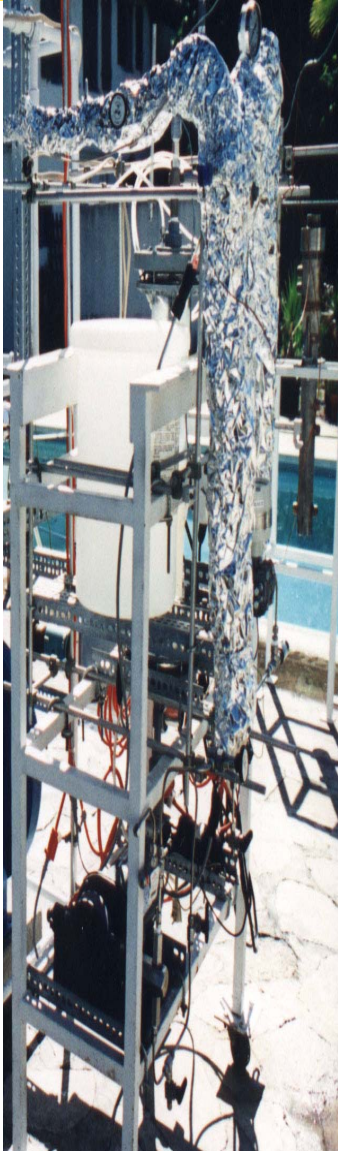


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PROTOTYPES



Phase I and II Prototype Reactors



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U₂ATM Background

□ Process characteristics

- ❖ Once through process
- ❖ Indirect heat exchange
- ❖ Closed water balance
- ❖ Reactor at equilibrium
- ❖ Predictable reaction dynamics
- ❖ Experience shows no reactor fouling due to side reactions

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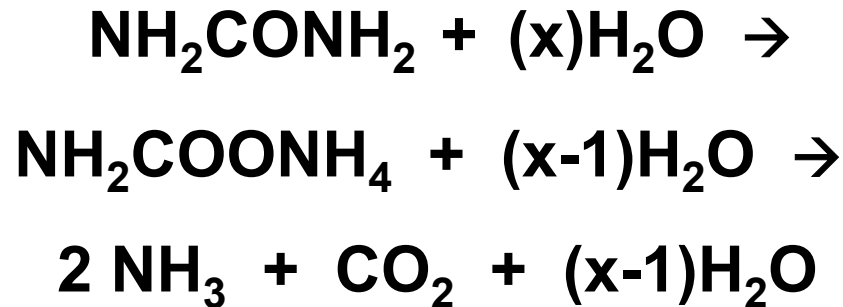


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Thermal Hydrolysis of Urea

Ammonia Generation from Urea:



- Urea hydrolyzes to carbamate
- Carbamate dissociates to ammonia and carbon dioxide
- Reaction is reverse of urea synthesis
- Generates only ammonia, water, carbon dioxide

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Formaldehyde

□ AES/Alamitos Results from January 2000:

- ◆ **No increase in reactor concentration ~1000 hours operation**
 - Feed 40% urea solution @ 0.2% formaldehyde = 1000 mg/l
 - Reactor liquor average from 5 samples = 1117 mg/l
- ◆ **HCHO is driven off in reactor**
 - 0.4 ppm increase in HCHO upstream of catalyst over baseline
 - Increase agrees with material balance for ~0.2% HCHO in urea
- ◆ **SCR catalyst provides catalytic oxidation of HCHO**
 - 0.02 ppm HCHO measured at stack after catalyst (>95%)

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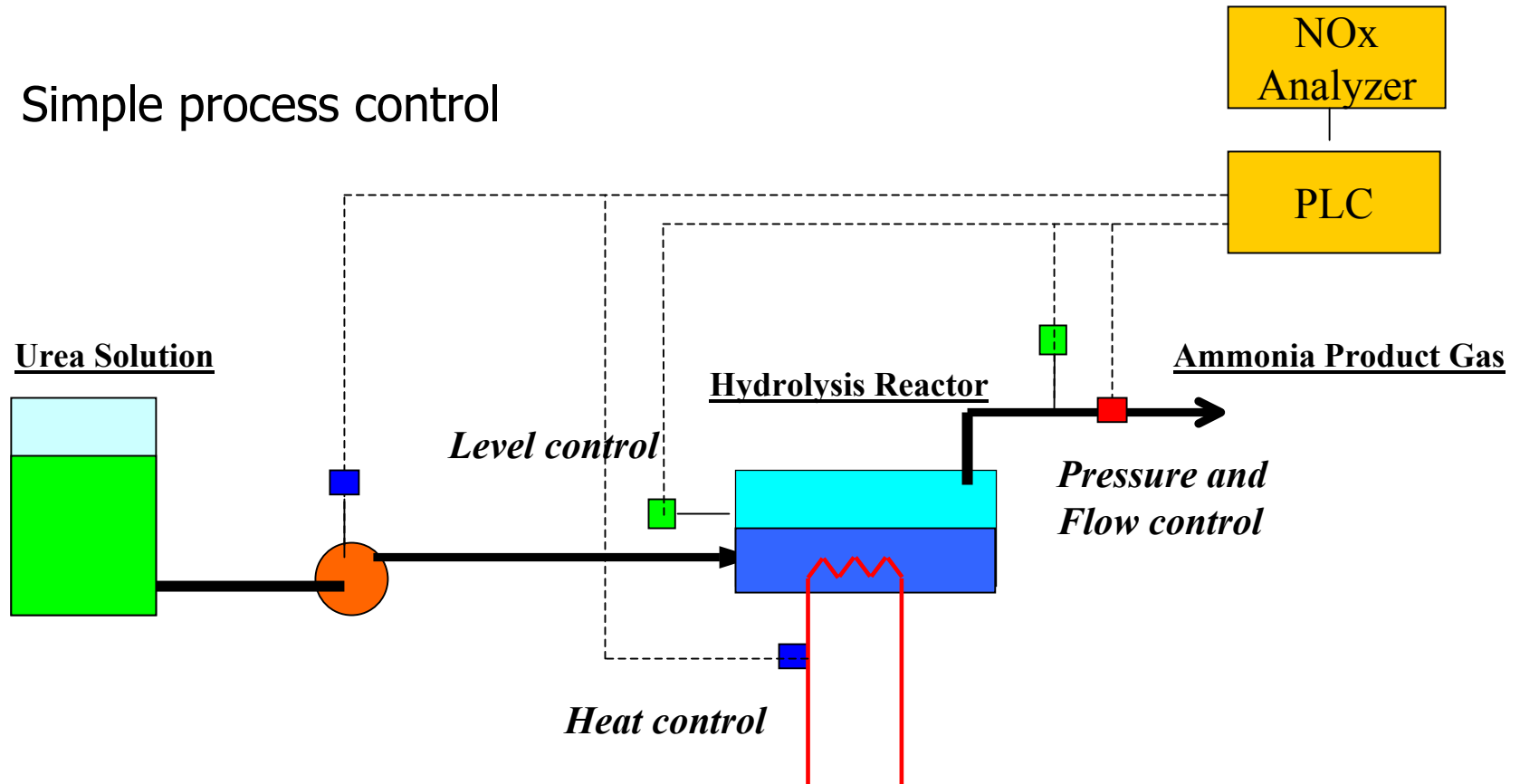


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***U₂A*TM Process Control**

- Simple process control



***U₂A*TM**

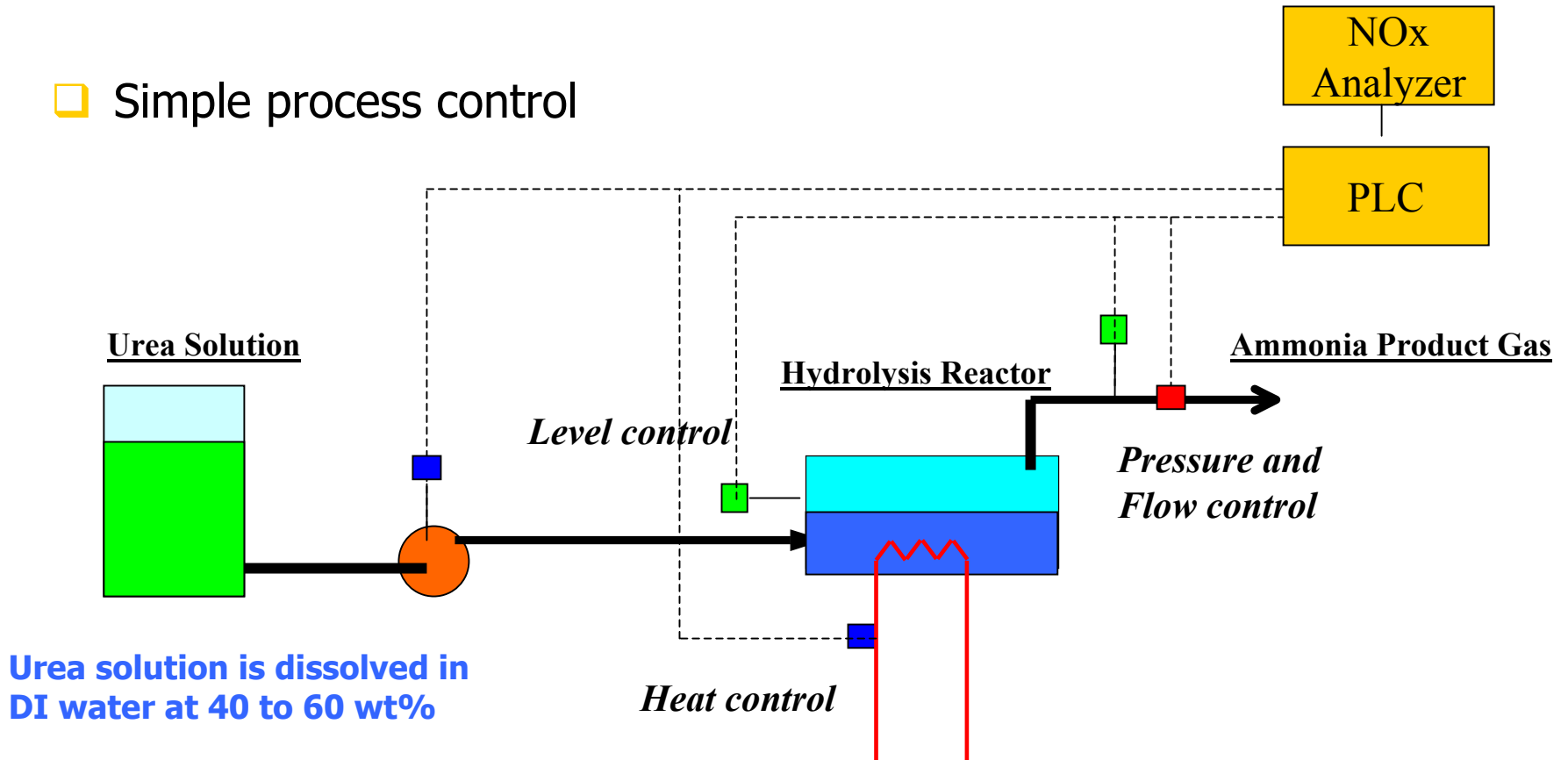


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U₂A™ Process Control

- Simple process control



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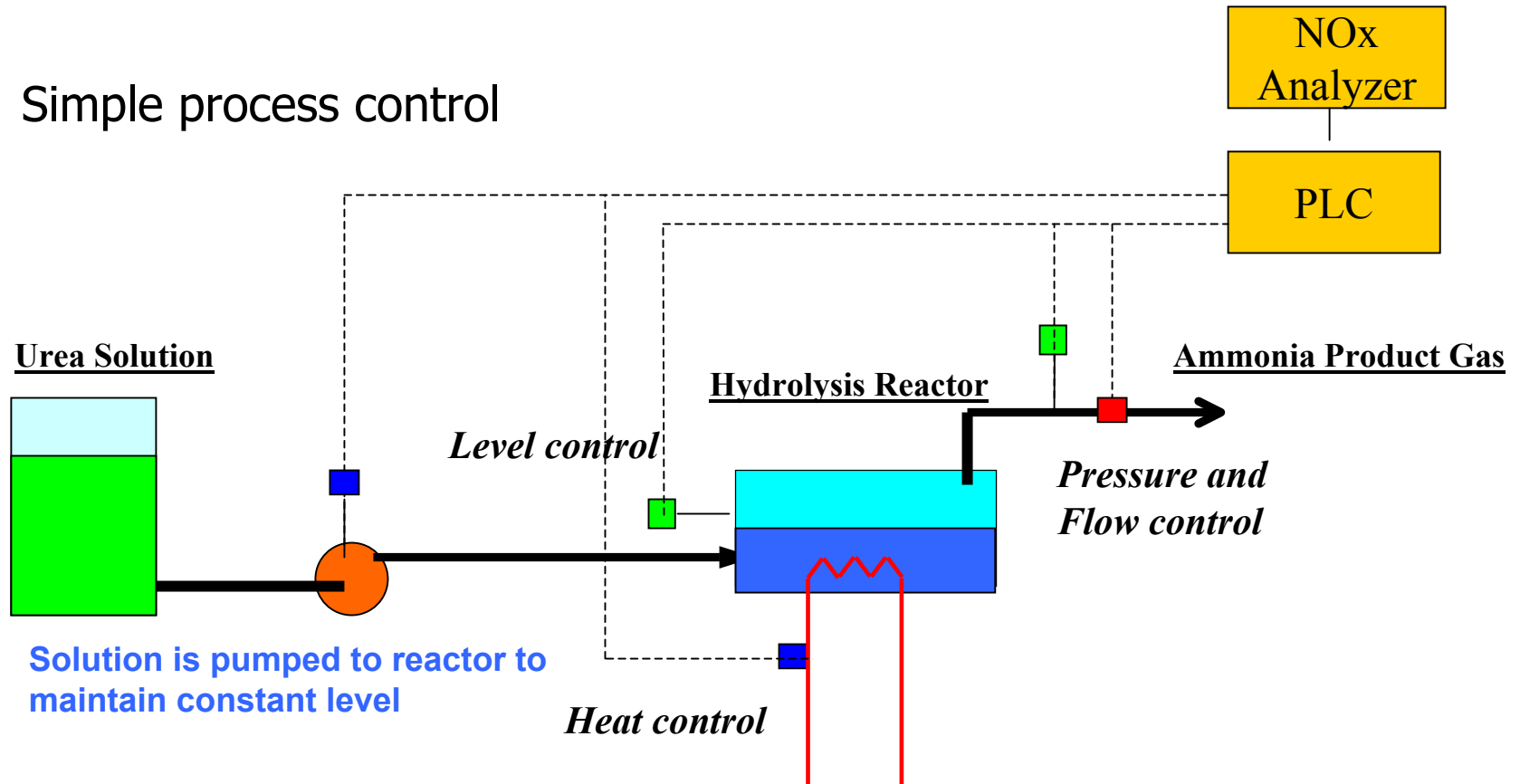
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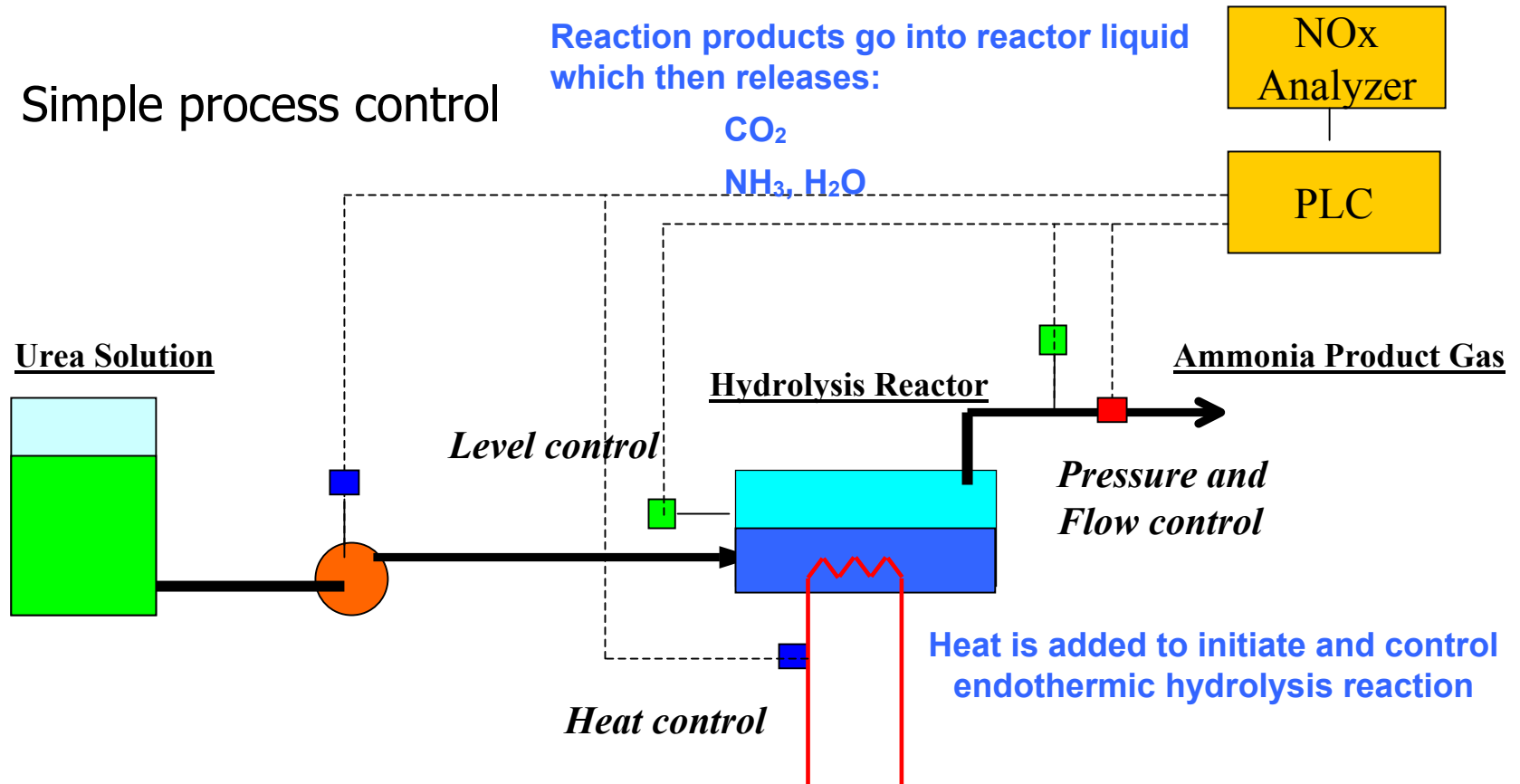
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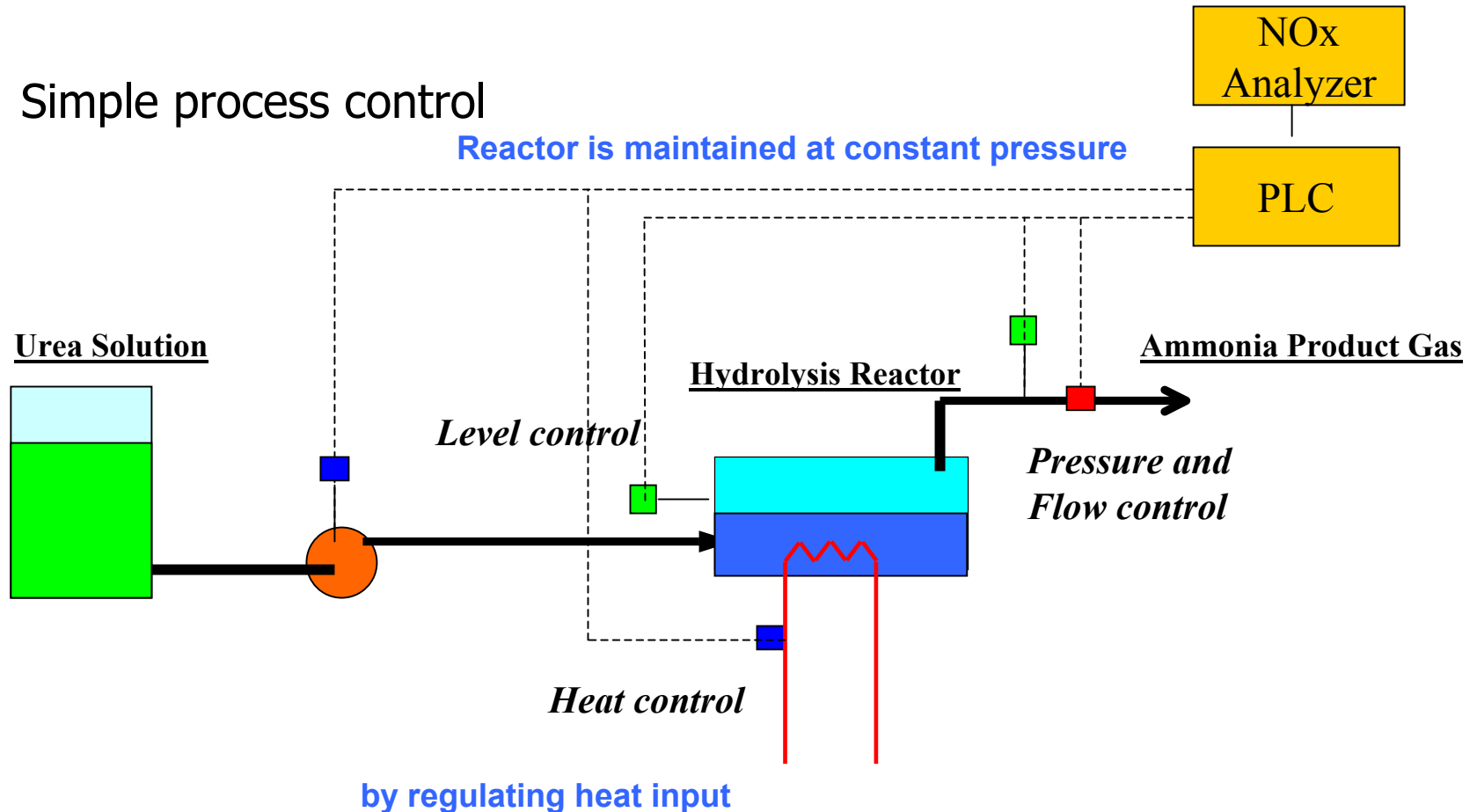
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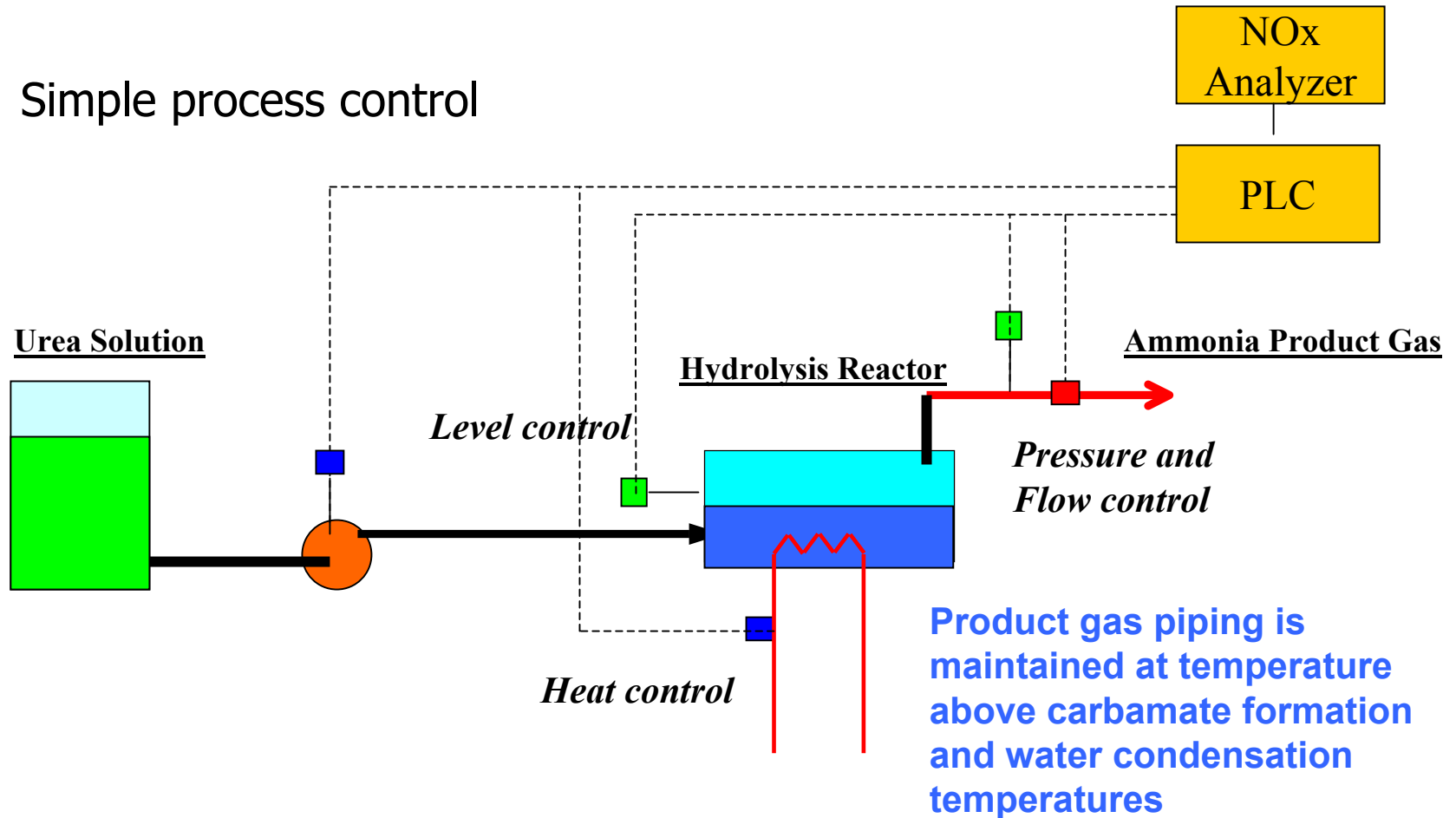


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12

U₂A™ Process Control

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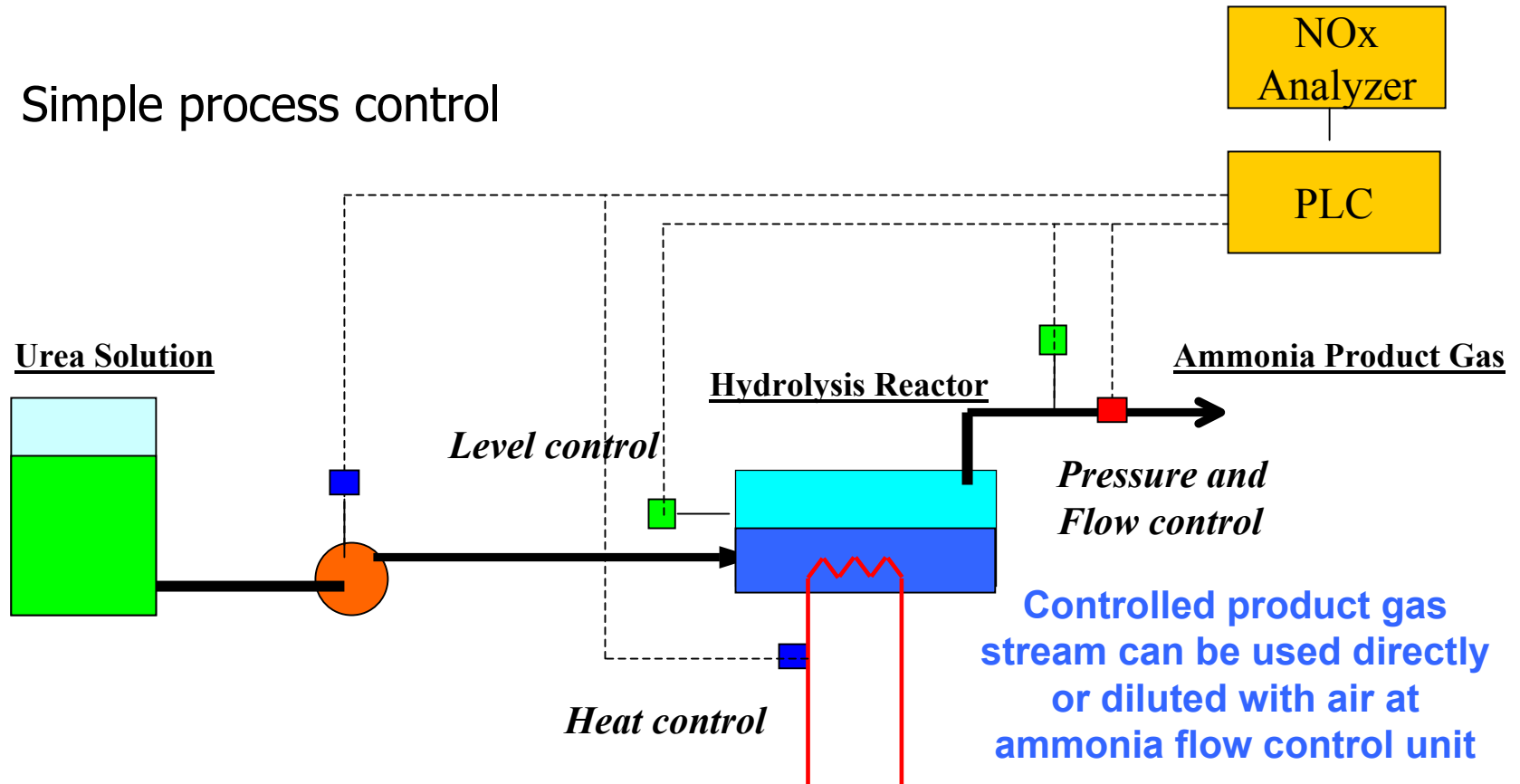
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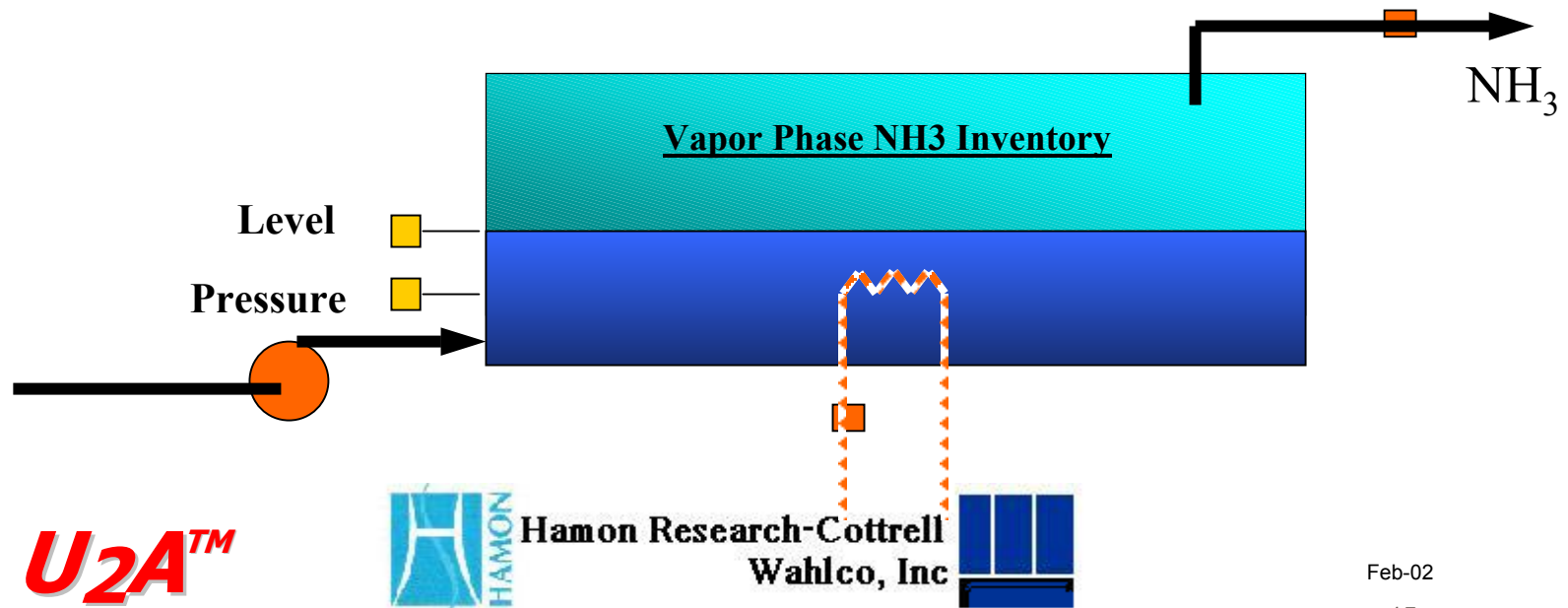
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Start Up

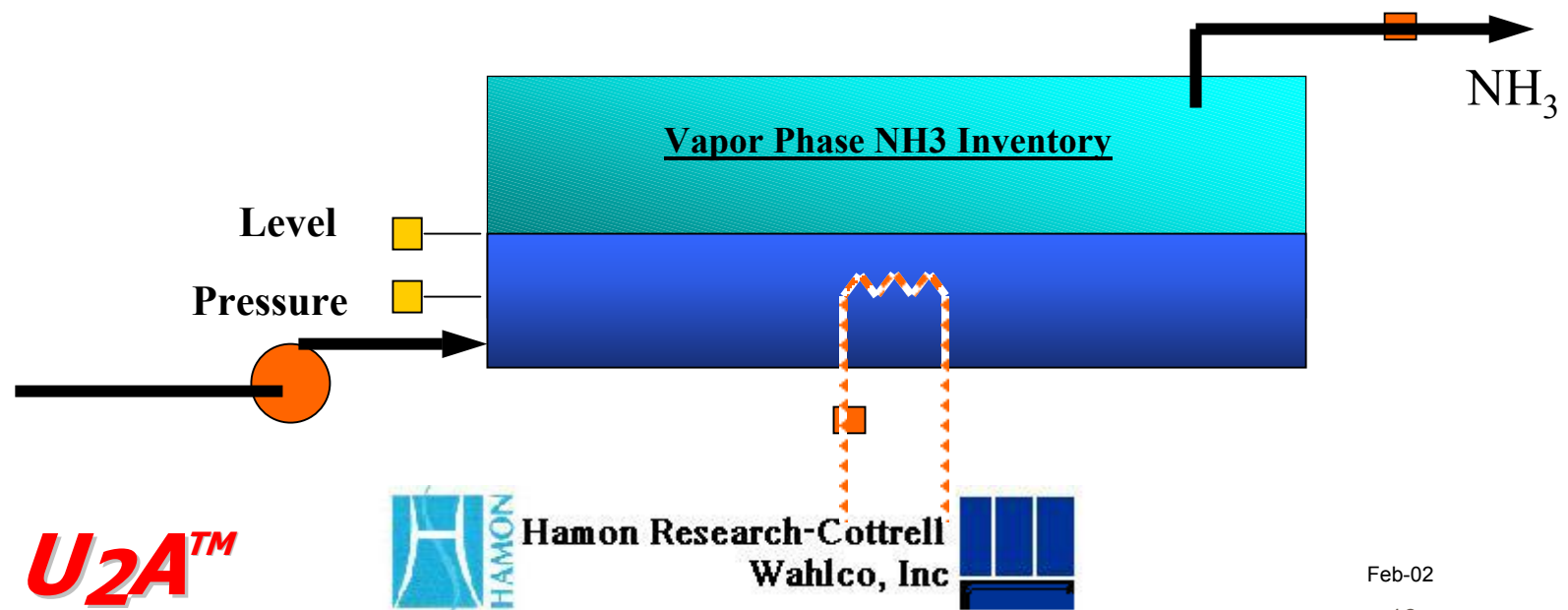
- ❑ Reactor contains equilibrium liquid from prior operation
 - ◆ Approximately 15%-20% urea or carbamate
 - ◆ Approximately 3% ammonia
- ❑ Heating mode in stages to achieve 250°F and 40 psig under temperature control
- ❑ Mode changes to injection under pressure control at 80 psig set point
- ❑ About 30-45 minutes from cold condition, 0-15 minutes from idles condition



Normal Operation and Ramping

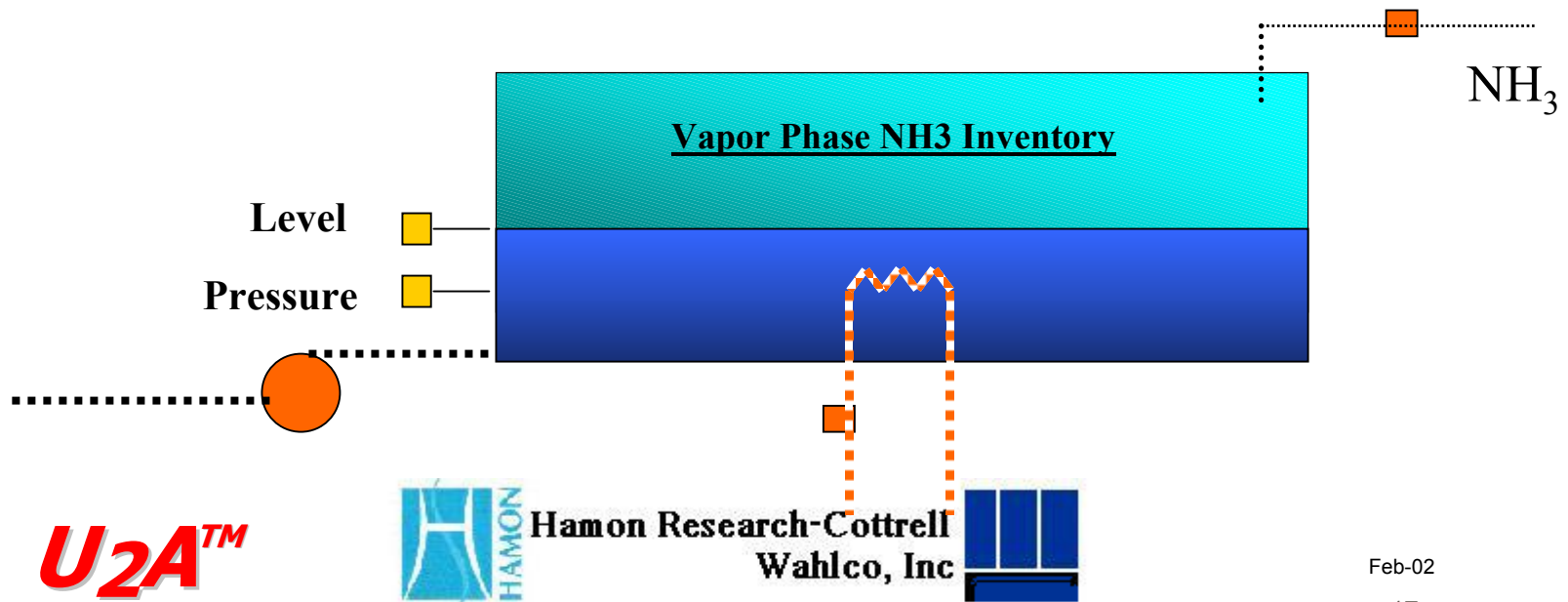
□ Injection mode

- ◆ Constant pressure and level
- ◆ Temperature and steam vary
- ◆ Vapor inventory (~1 minute) instantly available
- ◆ Change in heat input adjusts reaction rate to maintain reactor pressure (1 °F change yields ~5% change in rate)
- ◆ Level control maintains urea solution (~3 hours inventory)



Normal Shutdown

- Normal shutdown
 - ◆ NH_3 continues to process
 - ◆ Steam and feed pump shutoff
 - ◆ Reactor cools (due to endothermic reaction) and enters standby mode



U₂ATM Projects

<input type="checkbox"/> Allegheny Energy/Harrison Station	3,700 lb/hr
<input type="checkbox"/> Allegheny Energy/Pleasants Station	1,800 lb/hr
<input type="checkbox"/> AES/Alamitos Station	260 lb/hr
<input type="checkbox"/> AES/Huntington Beach Station	340 lb/hr
<input type="checkbox"/> DTE Energy/Monroe	10,000 lb/hr
<input type="checkbox"/> Constellation Energy/Wagner Station	460 lb/hr
<input type="checkbox"/> IST/Dominion Energy/Kauai	30 lb/hr

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Experience Review

□ AES/Alamitos

- ◆ 400:1 scale-up from pilot
- ◆ Boiler load following and NOx Compliance
- ◆ Comparison to 29% aqueous
- ◆ Formaldehyde analysis
- ◆ Reactor liquid and residual materials analysis
 - Predictable based on urea trace materials
 - No side reactions
 - Confirmed materials of construction



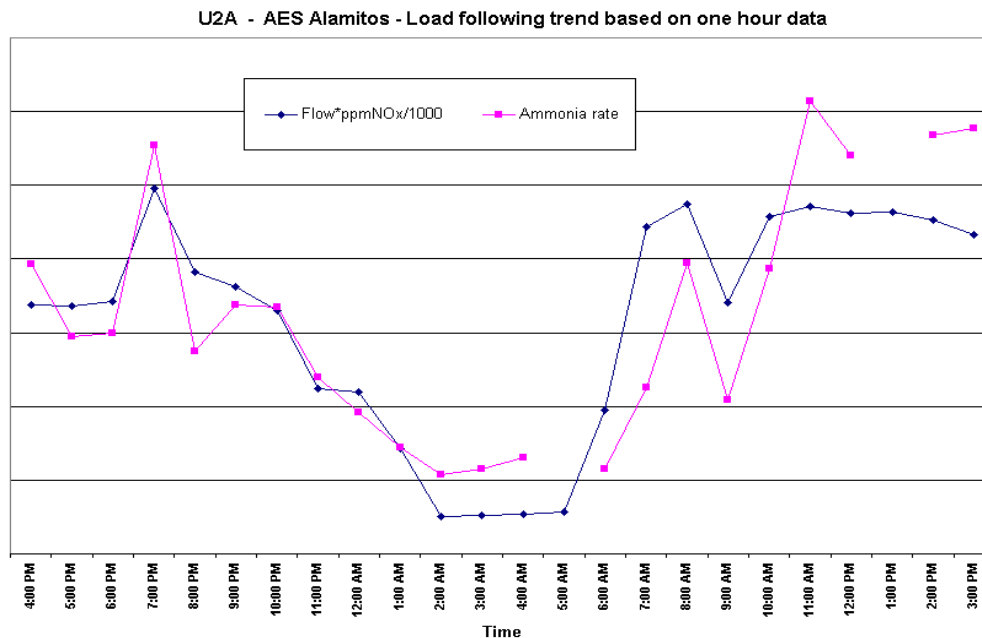
□ AES Huntington Beach

- ◆ Smooth start-up
- ◆ One day to automatic operation
- ◆ **Carbamate formation and heat tracing**
- ◆ 4000 operating hours to date



Load Following

- Process easily follows boiler load variations
 - ◆ AES Alamitos hourly averaged data
 - ◆ Approximately 10:1 turndown over typical daily cycling operation



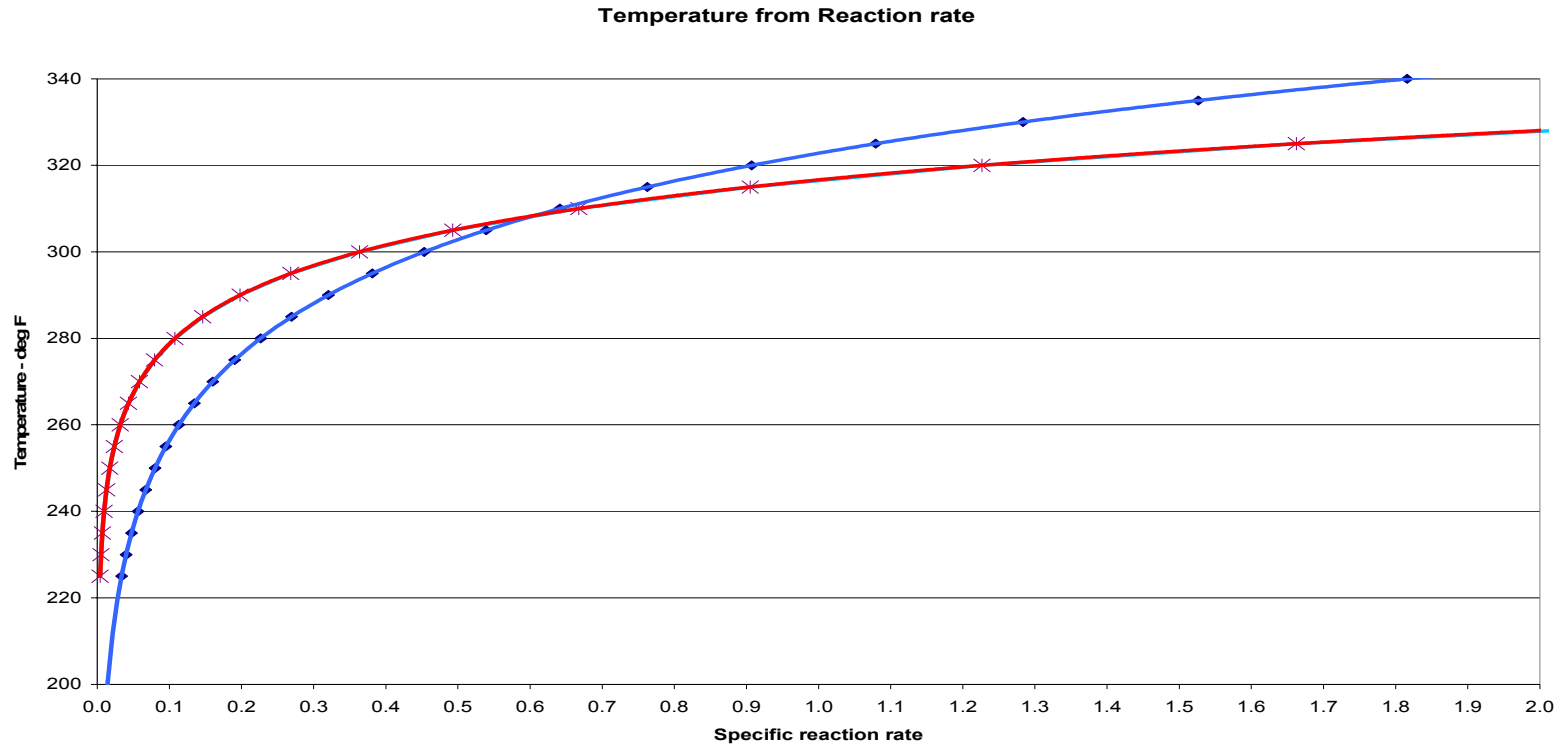
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Comparison of Prototype Operation to 400 lb/hr system



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Allegheny Energy Supply

Harrison and Pleasants

- ◆ The Harrison project was the first U2A commercial award and represents “new technology” risk for Allegheny.
- ◆ Phase I operations were planned to identify any issues with process design or procedures well in advance of May 2002 SCR start up.
- ◆ Phase I deemed successful by mid September 2001.
- ◆ Allegheny Energy/Harrison operation builds on U2A experience at AES/Alamitos and AES/Huntington Beach.



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***U₂A*TM – Allegheny Harrison**

❑ Allegheny Energy Supply Harrison Station

- ◆ 3700 lb/hr ammonia from urea
- ◆ Supply to 6 SCRs on 3 x 600MW
- ◆ Three 50% reactors

❑ Scope

- ◆ Urea dry storage, handling
- ◆ Urea solution preparation
- ◆ Hydrolysis reactors
- ◆ Ammonia flow control units

❑ Schedule

- ◆ First 1850 lb/hr reactor
 - operational in September 2001
- ◆ Unit #1 start up May 2002

❑ Test Results

- ◆ Exceeded rating by >20%
- ◆ Met load-following and safety goals



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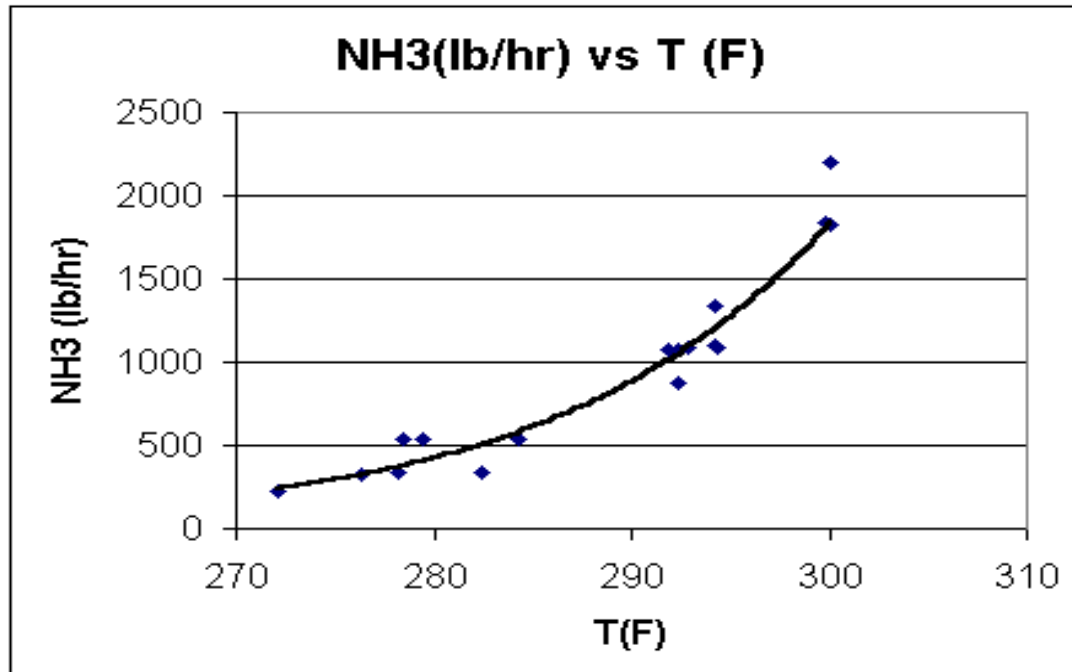


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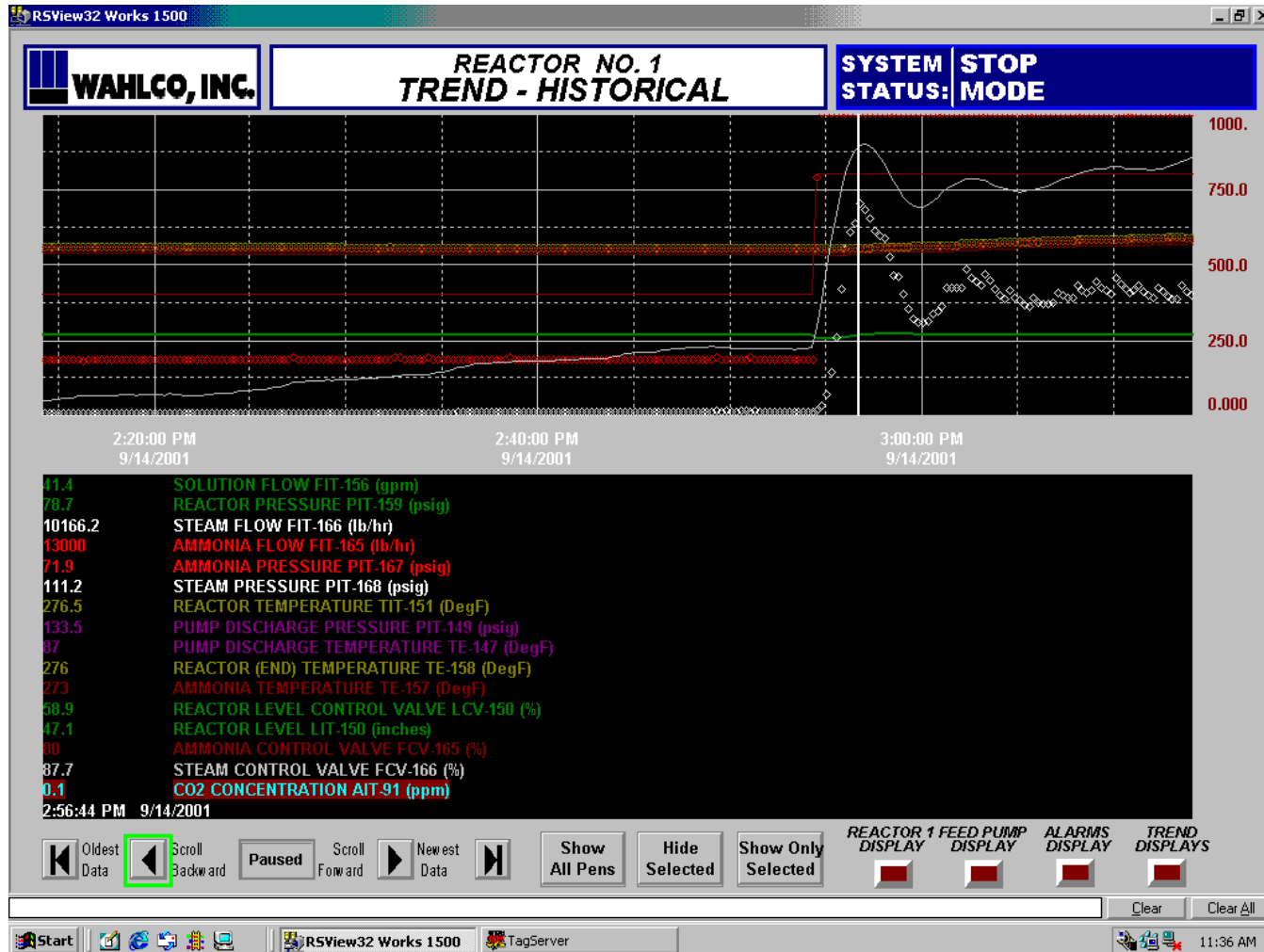
23

Harrison Phase I

- Production of Ammonia (lb/hr) vs. Temperature (F)
 - ◆ Data taken at/near equilibrium during manual operation
 - ◆ Full production temperature within a few degrees of prediction
 - ◆ Reactor capable well in excess of nominal rating



Instantaneous Ramp Up



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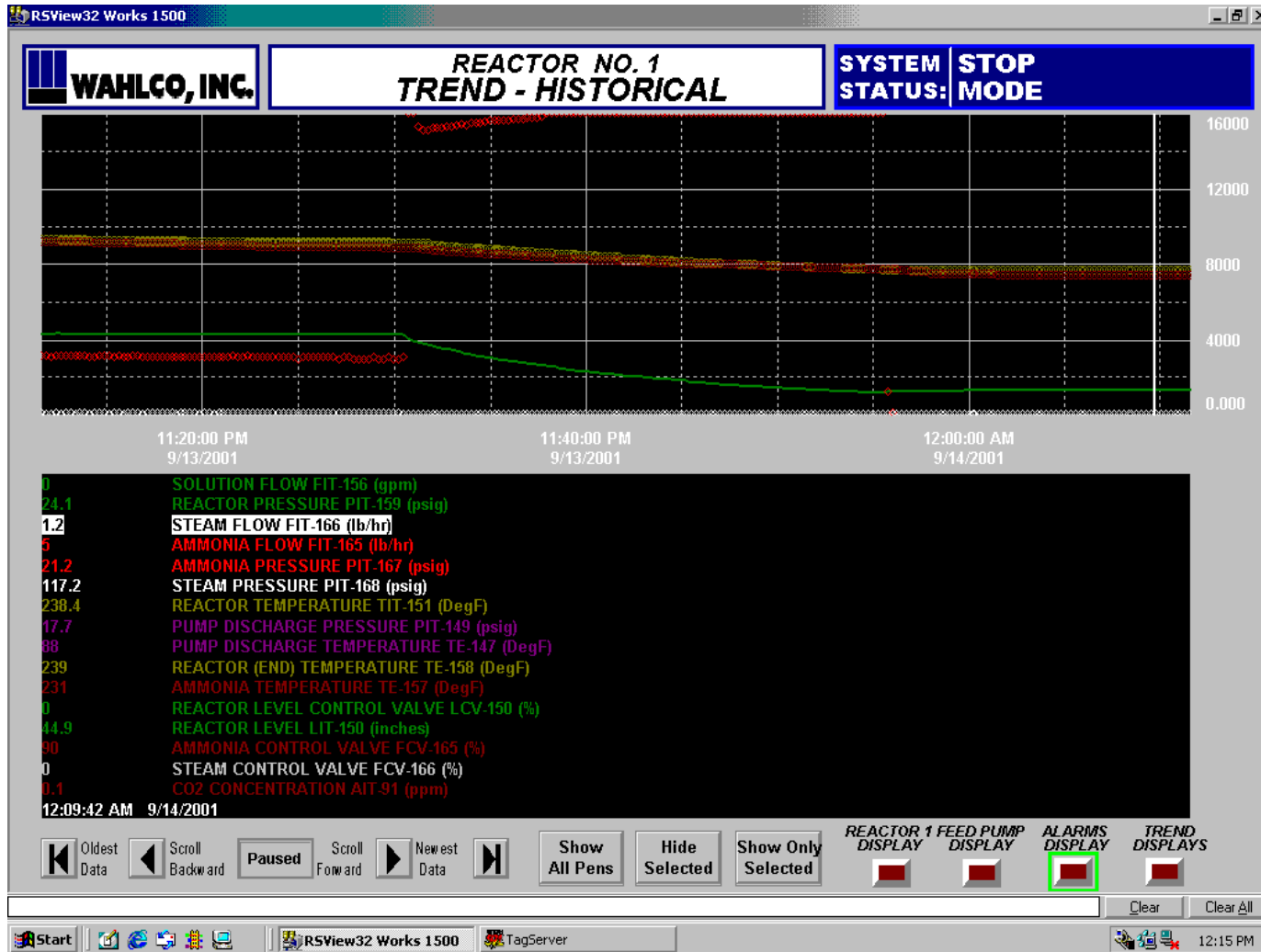


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Normal Shutdown



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Experience Review

□ Allegheny Energy Supply

Harrison Phase I

- ◆ Confirmation of process scale up
 - 2000:1 from pilot
 - 5:1 from AES
- ◆ Confirmation of start up/shutdown
- ◆ Heating characteristics for tube bundle
 - Instantaneous ramping



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27

What's Next?

❑ Allegheny Energy Supply

Harrison Phase II

Preparation for May 2002

- ◆ Start Up – Unit #1 SCR
- ◆ Balance of delivery/construction
- ◆ Urea supply and logistics
 - Urea supplier selection
- ◆ Urea dry storage
- ◆ Automated batch dissolving
- ◆ Two reactor operation
 - One operating, one standby

❑ Other U2A start ups – May 2002

- ◆ DTE/Monroe – one unit
- ◆ Constellation/Wagner



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