Safe Urea Decomposition Process for SCR NOx control on Campus Energy Generating Gas Turbines and Boilers

A&WMA 111th Annual Conference & Exhibition, Hartford, CT June 25-28, 2018

Abstract #400638

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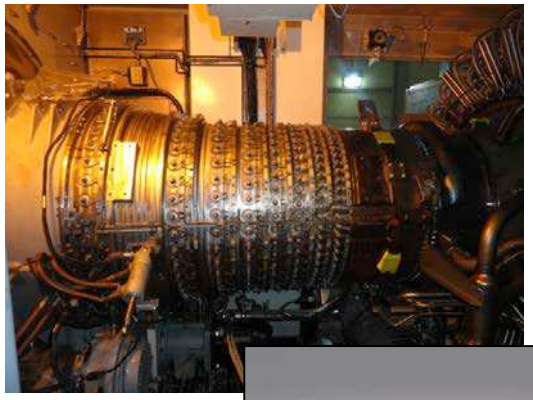
Campus Energy Generating Gas Turbines and Boilers

- Reliable power generation
- Population centers
- Limited option for evacuation
- Many indoor installations
- Frequent turn downs and shut-downs requiring quick start-up

- Typically <30 MW GT/HRSG or small package boilers
- Mostly natural gas fired
- SCR for NOx control
- Minimize hazardous material usage

➢ Safe, Clean, Reliable, Small, Redundant, Responsive

GE LM2500 w/Heat Recovery Steam Generator (HRSG) & SCR with Cormetech Catalyst



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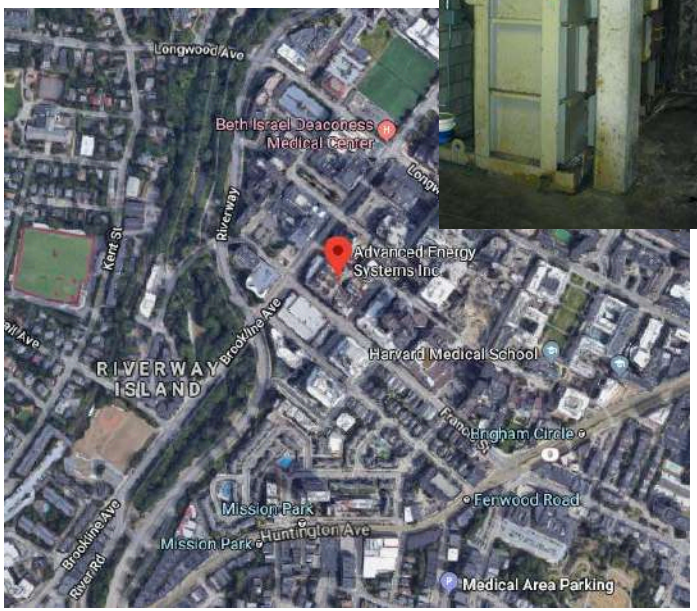
Campus Energy Generating Gas Turbines and Boilers



Medical Area Total Energy Plant (MATEP), Boston, MA

University of Texas, Austin TX

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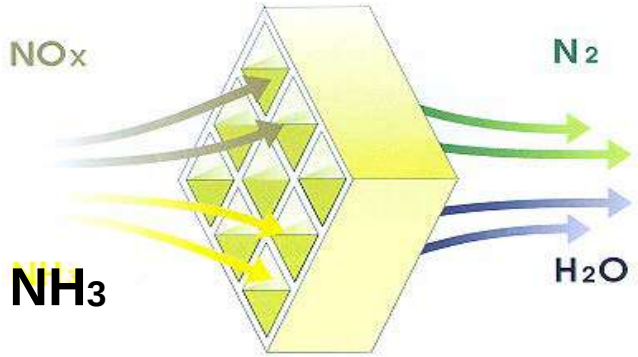
SCR for NOx control: Available Reagents for SCR

- NOx reacts with NH3 over catalyst to form N2 between 400 – 800 F depending on catalyst formulation
- Various reagents for SCR: urea, anhydrous ammonia, and aqueous ammonia systems
- Anhydrous ammonia is typically the first choice due to economics



$$4NO + 4NH_3 + O_2 \longrightarrow 4N_2 + 6H_2O$$

$$2NO_2 + 4NH_3 + O_2 \longrightarrow 3N_2 + 6H_2O$$

$$NO + NO_2 + 2\,NH_3 \longrightarrow 2N_2 + 3H_2O$$

Urea → NH3

$$NH_2\text{-}CO\text{-}NH_2 \xrightarrow{\text{gas phase decomposition}} NH_3 + HNCO$$

$$HNCO + H_2O \xrightarrow[\text{gas phase or catalyst}]{} NH_3 + CO_2$$

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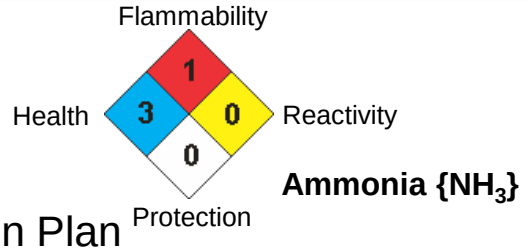
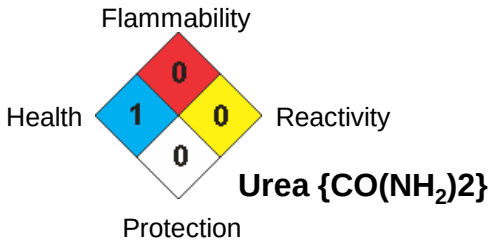
SCR System Reagent Options

- **Anhydrous Ammonia**
  - Least Expensive (Coming in the Gate)
  - Extremely Hazardous Chemical, Highest Risk
  - Requires RMP, Extensive Safety Training, Evacuation Plan



Ammonia {NH_3}

- **Aqueous Ammonia**
  - 29% Concentration – Limited Availability, No OSHA Relief
  - 19% Concentration – More Widely Available, No RMP
- **Urea for On-Site Ammonia Generation**
  - Significant Safety Advantages
  - Worldwide Commodity
  - No Impact on Catalyst Life or SCR Performance
  - Installed on Hundreds of Units Around the World



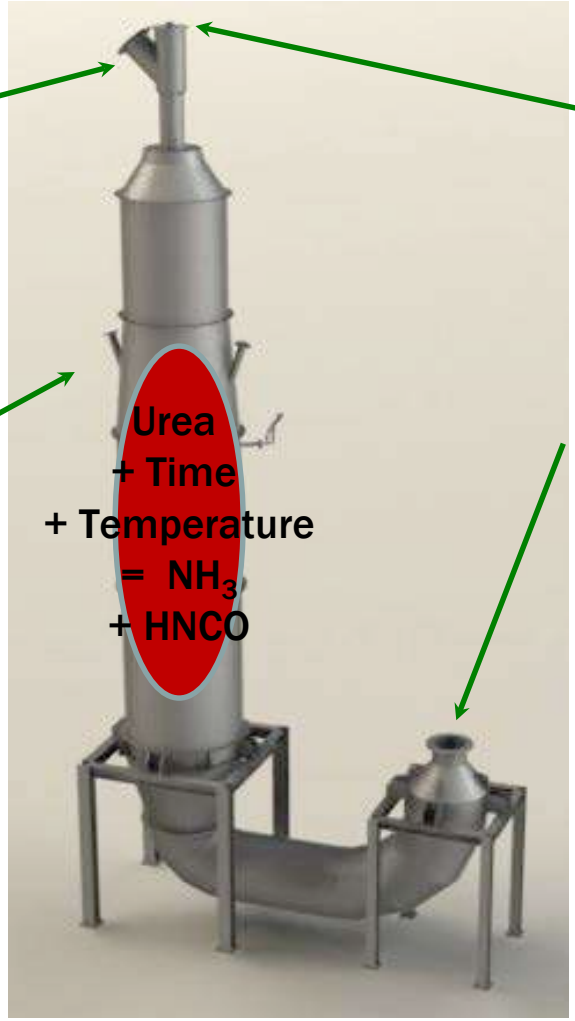
Urea {$CO(NH_2)2$}

- Significant increase in domestic production of urea due to Diesel Exhaust Fluid (DEF) Market and low natural gas pricing - High availability and lower pricing

Thermal On-line Decomposition of Urea simple, safe, fast response & shut down

Carrier Medium:
- Ambient Air
- Preheated combustion air
- Clean Hot Flue Gas (GT exhaust)

Aqueous Urea injection into Temperature and Time Controlled Chamber with <3 seconds residence time



Heat Source in the Form of Natural Gas Burner, Electric Heater

Process Delivers Reagent to NH_3 Injection Grid (AIG) at Required Pressure and Temperature Based on SCR Demand Signal

Maintain sufficient temperature to prevent urea or ammonium carbamate formation

No special form of urea needed

Negligible NH_3 in the system piping

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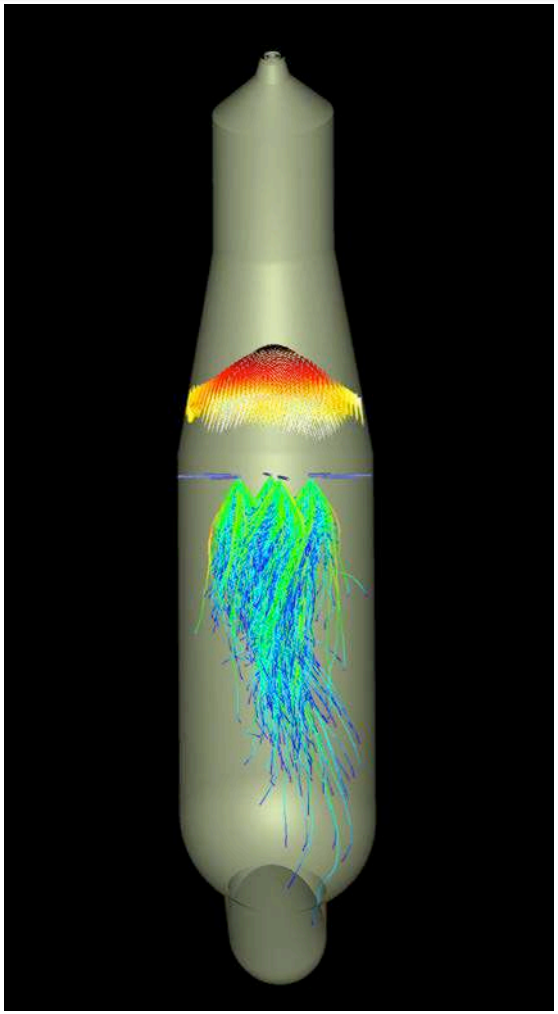
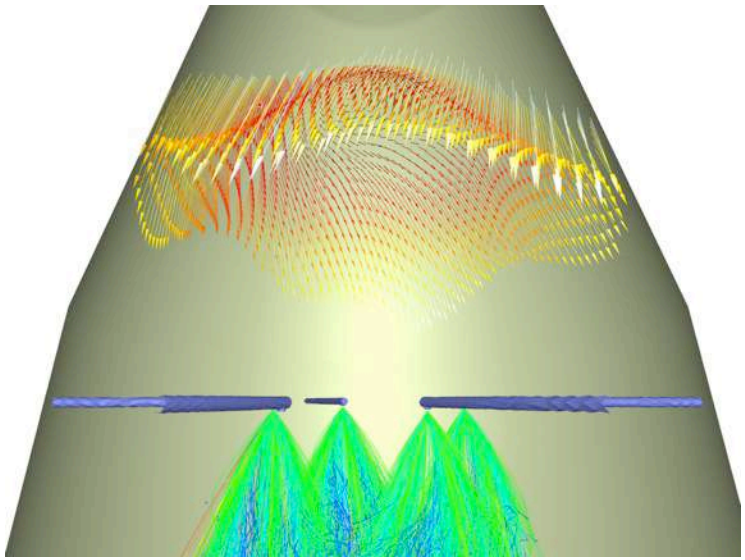
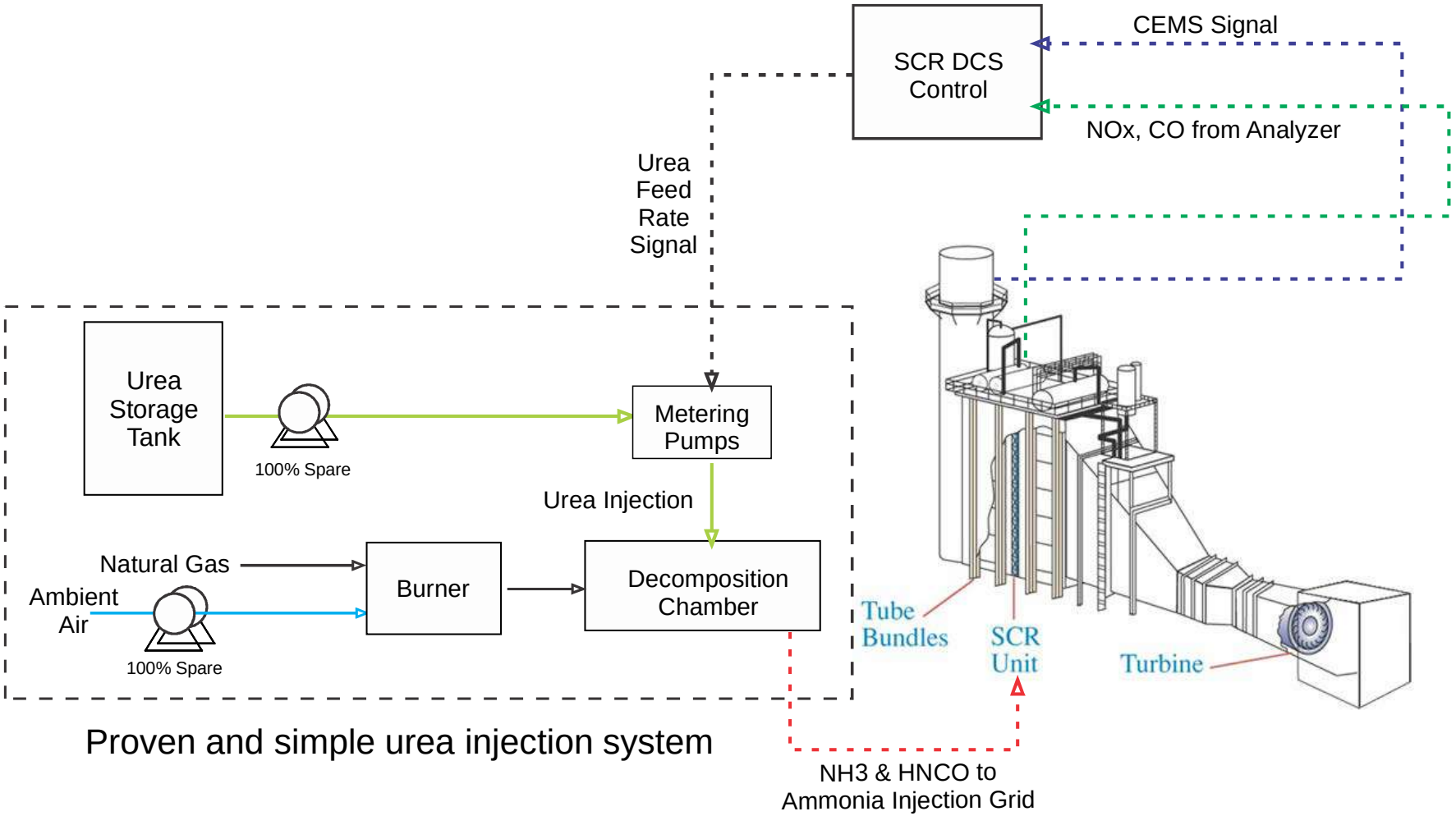
ULTRA™ Process Modeling





- Computational Fluid Dynamics (CFD) Modeling of Decomposition Chamber
- Modeling of Temperature, Residence Time, and Droplet Dispersion
- Evaluation of Urea Injection Strategies

ULTRA and SCR Process Schematic



Proven and simple urea injection system

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>250 Units Installed Worldwide

10 lb/hr ULTRA

1 lb/hr ULTRA

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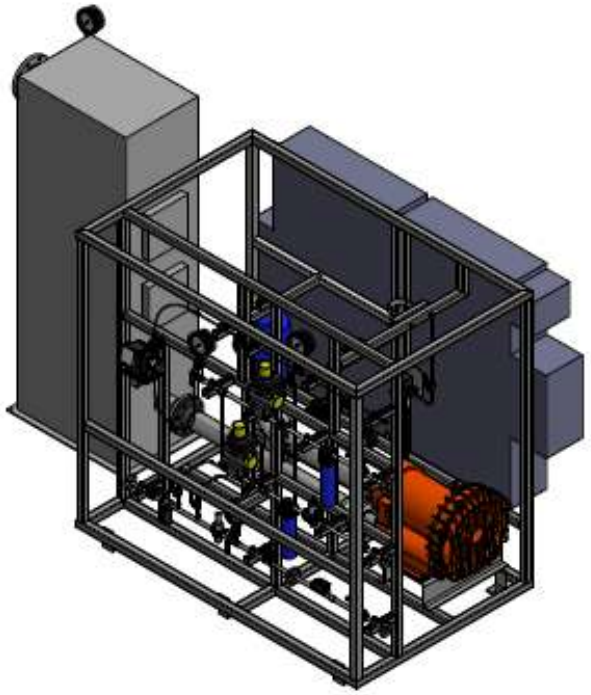
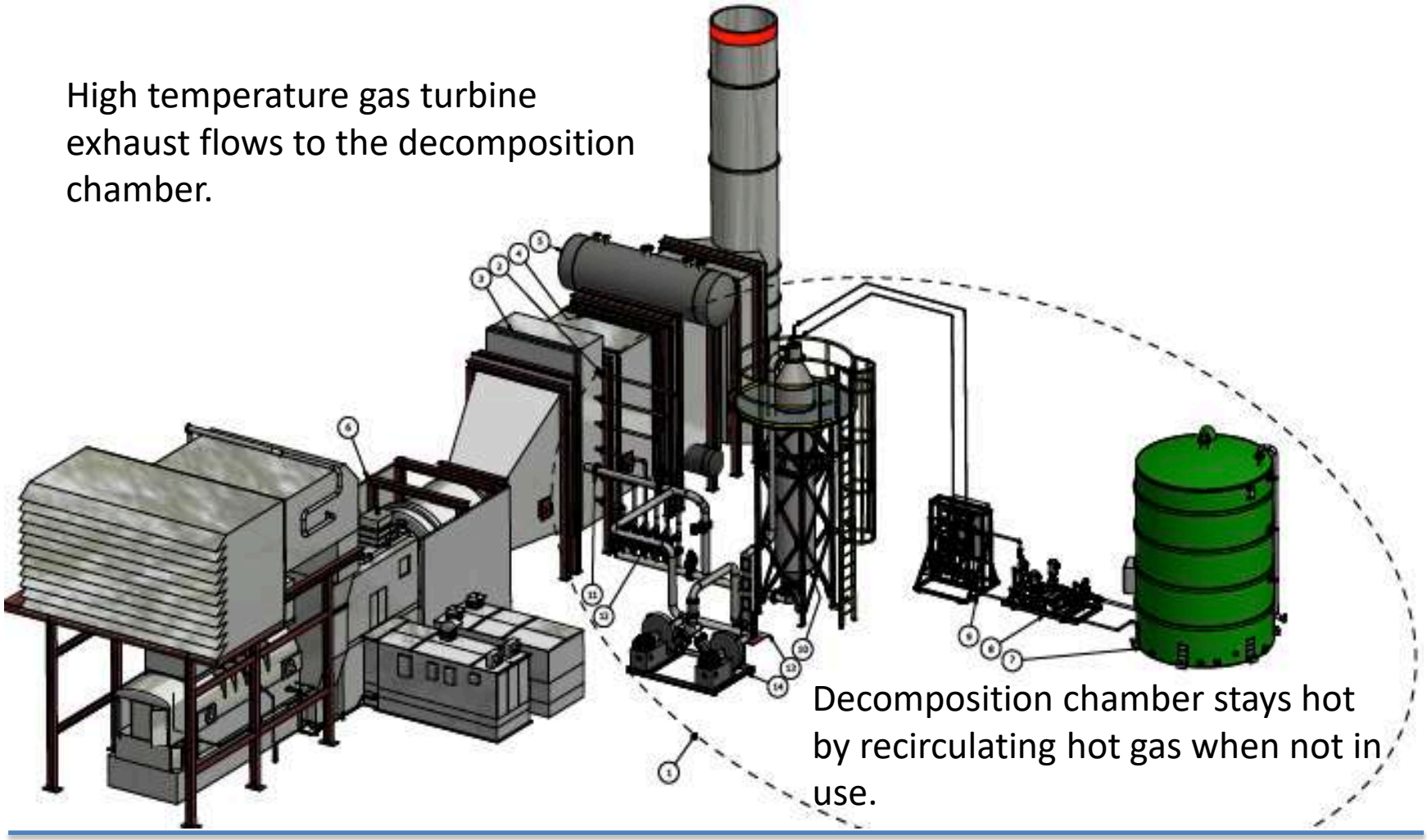
Recent ULTRA Developments for Campus CHP Plants

- Reduce heating by direct use of high temperature gas turbine exhaust gas
- Ammonia generation in <10 minutes from a standby mode if required
- Compact ULTRA for 1 #/hr NH3 demand designed and demonstrated
- Modularized equipment for ease of installation
- HNCO Hydrolysis catalyst lowers ULTRA outlet temperature limit from 450 F to 250 F



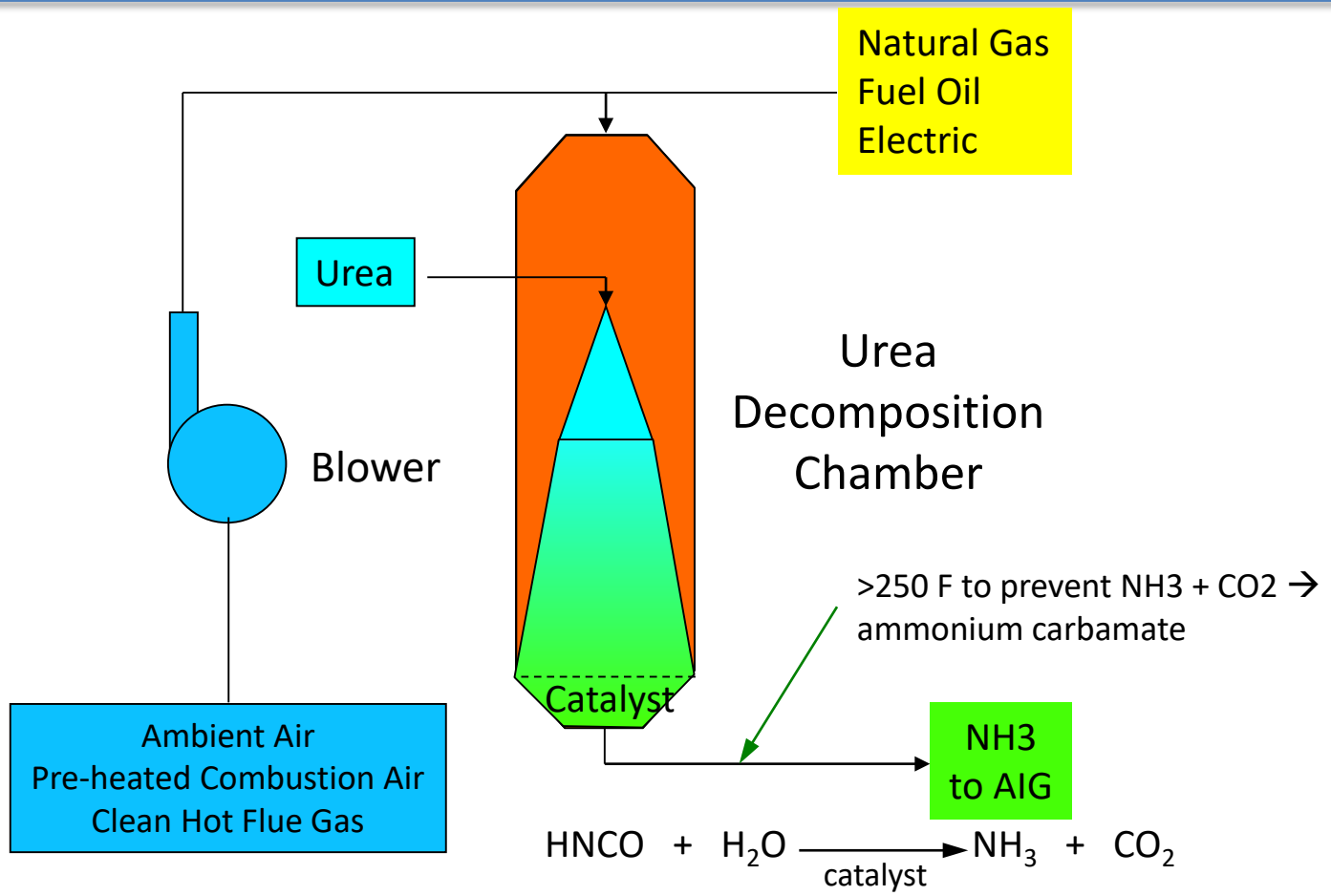
ULTRA-EX 10 SYSTEM-QS

High temperature gas turbine exhaust flows to the decomposition chamber.



Decomposition chamber stays hot by recirculating hot gas when not in use.

ULTRA w/HNCO Hydrolysis Catalyst



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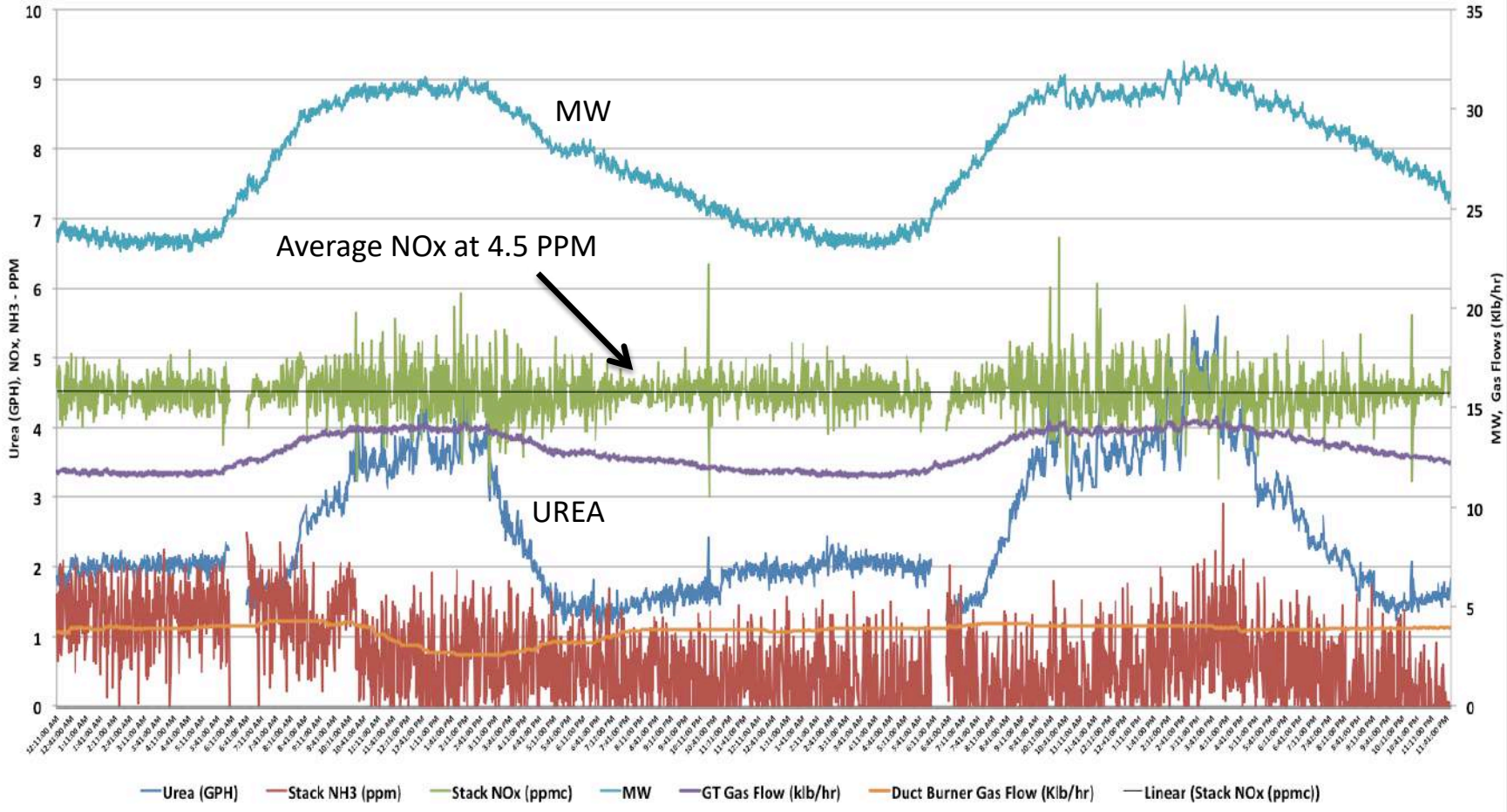
Case Study 1 – University of Texas, Austin: Combined Heat and Power Plant

- 32 MW GE LM2500 w/Heat Recovery Steam Generator (HRSG) & SCR with Cormetech CM-21 Catalyst
- System Designed for 40% or 32% Urea (40% Initial Operation). 10:1 turndown 2.5 to 25 lb/hr NH3
- Constrained Site
- 50,000 Students in the Region
- Campus Safety is Paramount

UT Austin SCR/ULTRA Performance

operating since 2008



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UT Austin Ultra Experience

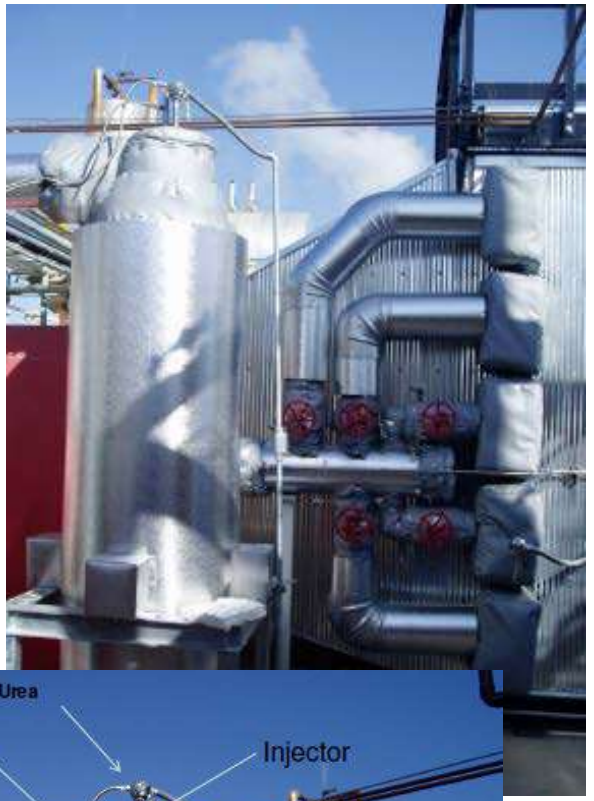
- Safest and Most Effective Alternative to the Use of Ammonia in UT Campus
- Met Overall Performance and Turndown Requirements
- Satisfied Need to Install within a Limited Footprint
- Competitive Economics

Case Study 2 – Harvard Blackstone CHP

- Combined Heat and Power (CHP) Expansion at Harvard University in Cambridge, MA
- New 7.5 MW GT and 51 mmbtu/hr Duct Burner fired HRSG
- Indoor installation
- 1.5 to 10 lb/hr NH3 Demand
- 130 KW electrical heater
- Equipment redundancy
- Limited Footprint - modified equipment configuration to fit in tight constrained area.
- Operational since early 2015
- Maintained NOx below the limit of 5 ppm

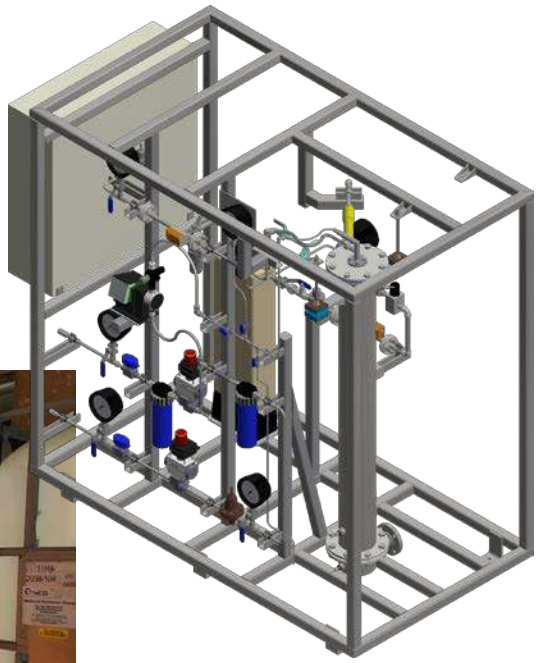
Case Study 3 – California

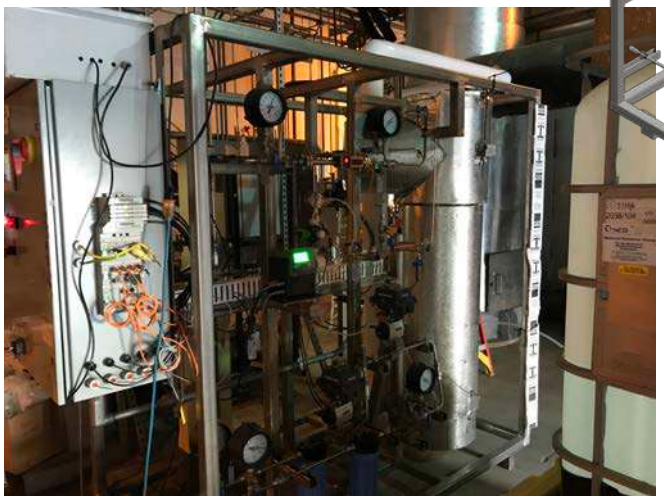
- Designed for 1 to 2 lb/hr NH3 for two (2) side by side 2.5 MW Gas Turbines
- Located inside a secure perimeter – difficult evacuation in case of emergency
- 32% Urea solution
- SCR NH3 demand
  - 1.5 lb/hr w/ GT water injection
  - 5 lb/hr at less than 1.2 MW and no water injection
- Maintained NOx below the limit of 5 ppm



Case Study 4: 1 #/hr Compact ULTRA

- Short term demonstration at a California State Facility
- Indoor 50,000 lbs/hr Auxiliary boiler – a backup to a Cogen unit.
- Designed for 1 lb/hr NH3 demand for an auxiliary package boiler → 0.6 GPH of 32.5% urea solution (DEF)
- One skid: 7'H, 4'W, 8'L
- Plant compressed air
- 30 kW Electrical heating
- HNCO hydrolysis catalyst
- 250 F AIG inlet temperature





✓ **Continuously generated NH3 from urea to maintain NOx below 5 ppm limit**

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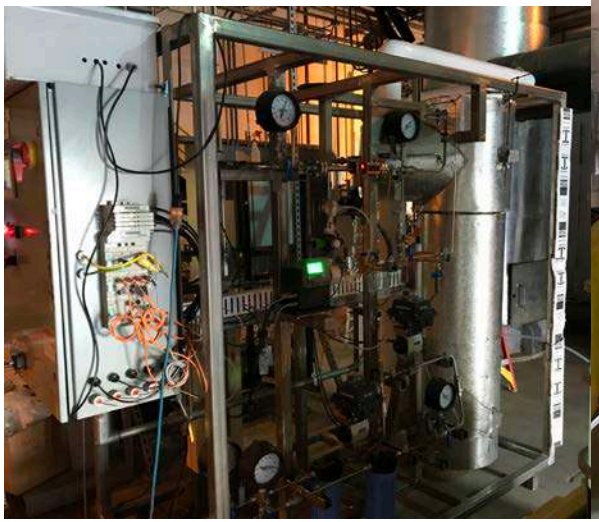
Ultra Decomposition Chamber and AIG Inlet



ULTRA Experience on Campus CHP and Steam Generating Units

OWNER	UNIT/ LOCATION	UNIT TYPE	PLANT SIZE	NH3 Rate (lb/hr)	ULTRA HEAT SOURCE	STARTUP DATE
College Campus	MA	GT/HRSG	22 MW	34	Flue Gas	2019
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LA County	CA	Pkg Boiler	50K pph steam	1	Electric	2017(D)
Harvard University	Cambridge, MA	GT/HRSG	7 MW	10	Electric	2015
California State	CA	HRSG	5 MW	2	Electric	2012
LA County	CA	HRSG	20 MW	16	Electric	2010
University of Texas	Austin, Texas	GT/HRSG	33 MW	33	Gas	2008
University of California	Irvine, CA	GT/HRSG	14 MW	11	Electric	2007
MATEP	Boston, MA	GT/HRSG	15 MW	15	Electric	2002
MATEP	Boston, MA	GT/HRSG	15 MW	15	Electric	2002

Conclusions

- Safe, effective and economical alternative to the use of ammonia in campuses or other populated areas with limited evacuation options.
- Achieved Overall Performance and Turndown Requirements in all Installations
- No byproduct, no blowdown, no corrosion,
- Fast Load Following Controls for steady NOx control and minimize NH3 slip
- Rapid shutdown with no residual ammonia in the system
- Installed in limited indoor or outdoor footprints
- Accepted by SCR and catalyst providers
- Designed for Maximum System Availability and Minimum Maintenance

ULTRA attributes:

- ✓ Simple Process and Controls
- ✓ Low Pressure Operation/Process
- ✓ Skid Mounted Systems for Easy Installation
- ✓ Proven Component Experience in over 900 Urea Based SNCR and ULTRA Systems