EXHIBIT 1

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Improving SCR Performance on Simple-Cycle Combustion Turbines

06/01/2010 | Terry McTernan, PE, Cormetech

PRINT MODE : ON

Austin Energy replaced the selective catalytic reduction (SCR) catalyst twice over five years for its four peaker turbines. The duct modifications and injection grid redesign, combined with new catalyst, are producing high NO_x reduction and low ammonia slip, and the catalyst is now expected to last at least five years.

Austin Energy (AE) owns the Sand Hill Energy Center (SHEC), a 500-MW power plant with a natural gas combined-cycle unit and four simple-cycle peaking combustion turbines. With typical high summer demands for the growing Austin area and record electric peaks in 2009, SHEC relies on its four General Electric LM-6000 combustion turbines for on-demand capacity. Those turbines together experience approximately 350 start/stops per year. As shown in Figure 1, each combustion turbine has a dedicated selective catalytic reduction (SCR) unit for NO_x reduction to meet the plant’s stack emission permit limits.

1. Four peakers. Austin Energy's Sand Hill Energy Center includes four 50-MW simple-cycle combustion turbines for peaking service that are equipped with SCRs. Also present on the plant site is a 480-MW combined-cycle plant. Work is under way to add two additional 50-MW peaker combustion turbines with start-up scheduled later this year. Courtesy: NEPCO

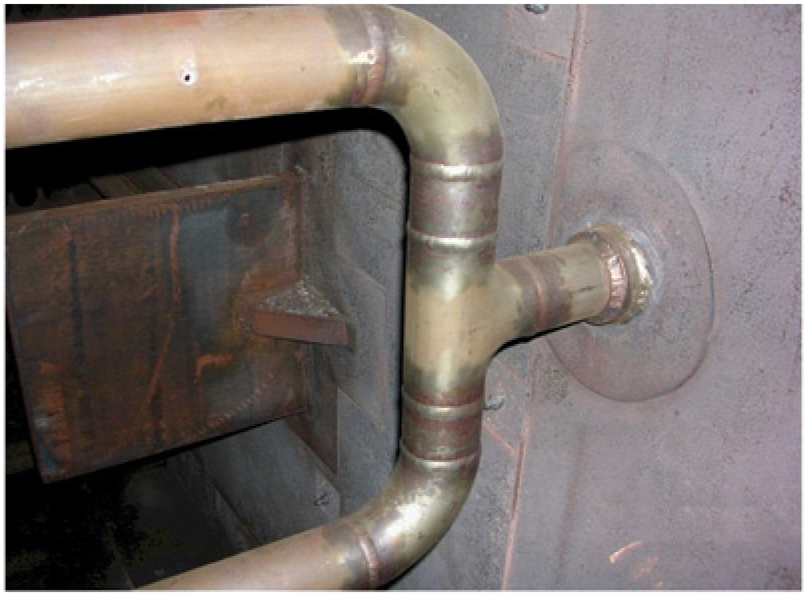
In 2006, after the SCR catalyst in the peakers had been replaced twice over a period of five years, AE decided to take a closer look at SCR catalyst performance. A study of operational data along with chemical analysis of the catalyst showed significant catalyst deterioration had occurred. AE issued a request for proposal and scope of work that covered measuring/modeling flue gas velocity distribution, evaluating the design of the ammonia injection grid (AIG), and replacement of existing wash-coated catalyst with extruded homogenous SCR catalyst. The performance requirements for the new catalyst design were 90% NO_x reduction with 5 ppm ammonia slip for a period of five years or 15,000 hours of operation.

After careful evaluation of proposals, Cormetech Inc. was selected by AE to provide the SCR catalyst product replacement and to evaluate overall system performance. A three-phase project approach was recommended in July 2007. The remainder of this article reports the results achieved for each of the three project phases.

Phase I: Investigation and Evaluation

Cormetech's testing of the existing catalyst samples confirmed that deactivation was severe and attributable to loss of the wash coat and sodium poisoning. The deteriorated condition of the catalyst confirmed that SHEC would need to take action in order to replace the catalyst in order to ensure meeting its emission requirements.

In addition, an initial inspection of the AIG lances revealed that the injection holes were 12 inches from either side of the duct walls (Figure 2). This injection gap was causing a starvation of ammonia to a portion of the flue gas stream, thereby permitting flue gas to pass through the SCR system essentially untreated.



2. Just passing by. An inspection of the ammonia injection grid lances found that ammonia was not thoroughly mixing with the flue gas, thereby allowing a portion of the gas stream to pass through the catalyst untreated. This figure illustrates a “two-prong” ammonia injection grid design (AIG). Courtesy: Cormetech

Test ports were installed on Unit 1 to complete the performance assessment. The ports were located in three areas: downstream from the SCR catalyst, upstream from the SCR catalyst, and upstream from the AIG. Flue gas testing was completed to assess velocity, temperature, and ammonia to NO_x variation. This testing confirmed a maldistribution of ammonia within the flue gas stream as well as poor distribution of flow and temperature at medium- and low-load conditions.

The catalyst condition and flue gas test results were reviewed in September 2007. Following this review, SHEC requested expedited delivery of the replacement catalyst to meet its planned December 2007 maintenance outage schedule. At the same time, SHEC authorized commencement of the Phase II process modeling to understand the flow and ammonia distribution concerns.

During the December 2007 outage, turnkey SCR catalyst replacement was completed in less than two weeks, with 12 new custom-designed modules installed within each of the four units (Figure 3). For each unit, a sample tray was incorporated to allow for easy removal of catalyst samples for evaluation, as shown in Figure 4. During future outages, the samples can be quickly removed and a replacement catalyst element installed. The sample is then returned to Cormetech for analysis and to assist with catalyst management planning. This approach precludes the need for rigorous drilling of the catalyst to extract core samples.

3. Complete replacement. The SCR assemblies for all four combustion turbines were replaced in less than two weeks during the December 2007 outage. Courtesy: Cormetech

4. Process improvement. A sample tray was added to each of the new catalysts to ease access when collecting catalyst core samples for laboratory analysis. Drilling of the catalyst to collect a sample is no longer required. Courtesy: Cormetech

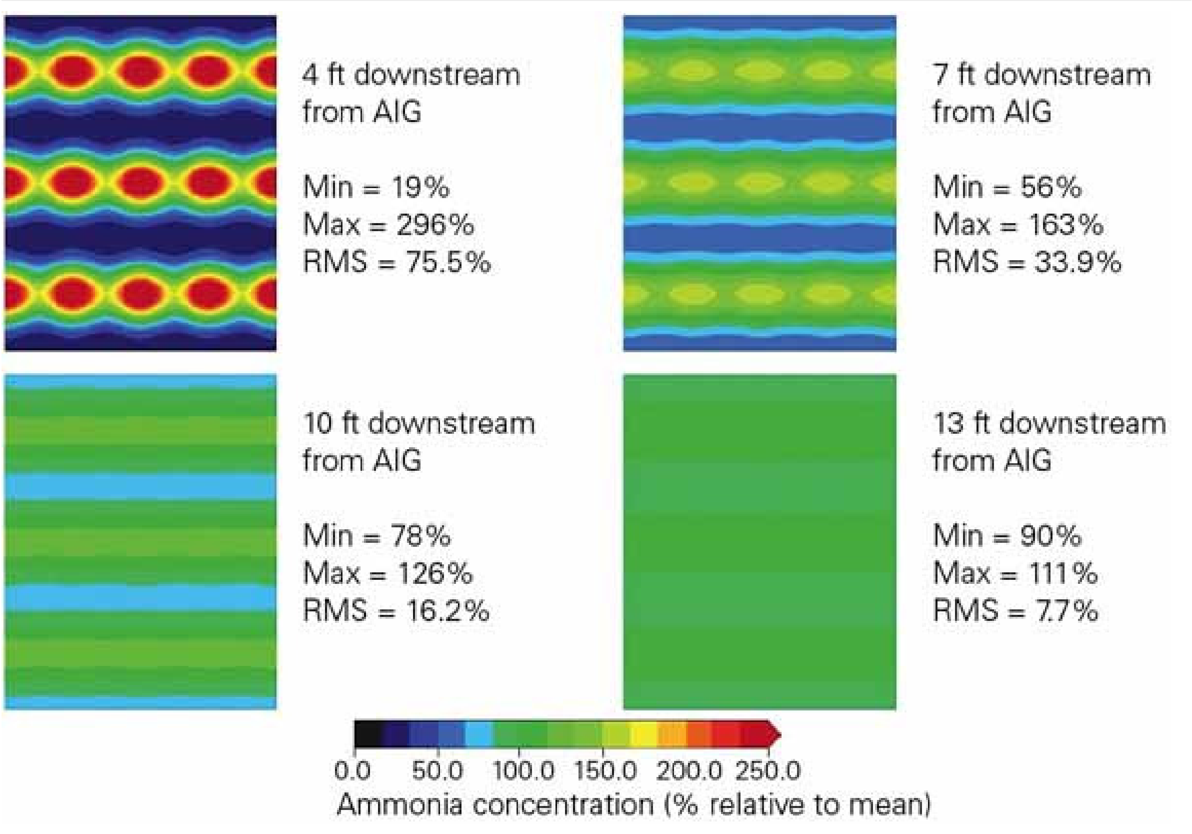
Also during this work, sample ports were installed downstream of the SCR catalyst in the three remaining units. The SCR systems on all units were successfully started up and met site emission requirements for 90% NO_x reduction; however, ammonia emissions were higher than the design predicted.

A simplified test was run after start-up that revealed significant ammonia to NO_x stratification requiring further investigation. Inadequate ammonia:NO_x distribution can pose problems of inadequate NO_x reduction, higher ammonia usage, and localized regions of high ammonia slip.

Phase II: Process Modeling and Design Improvement

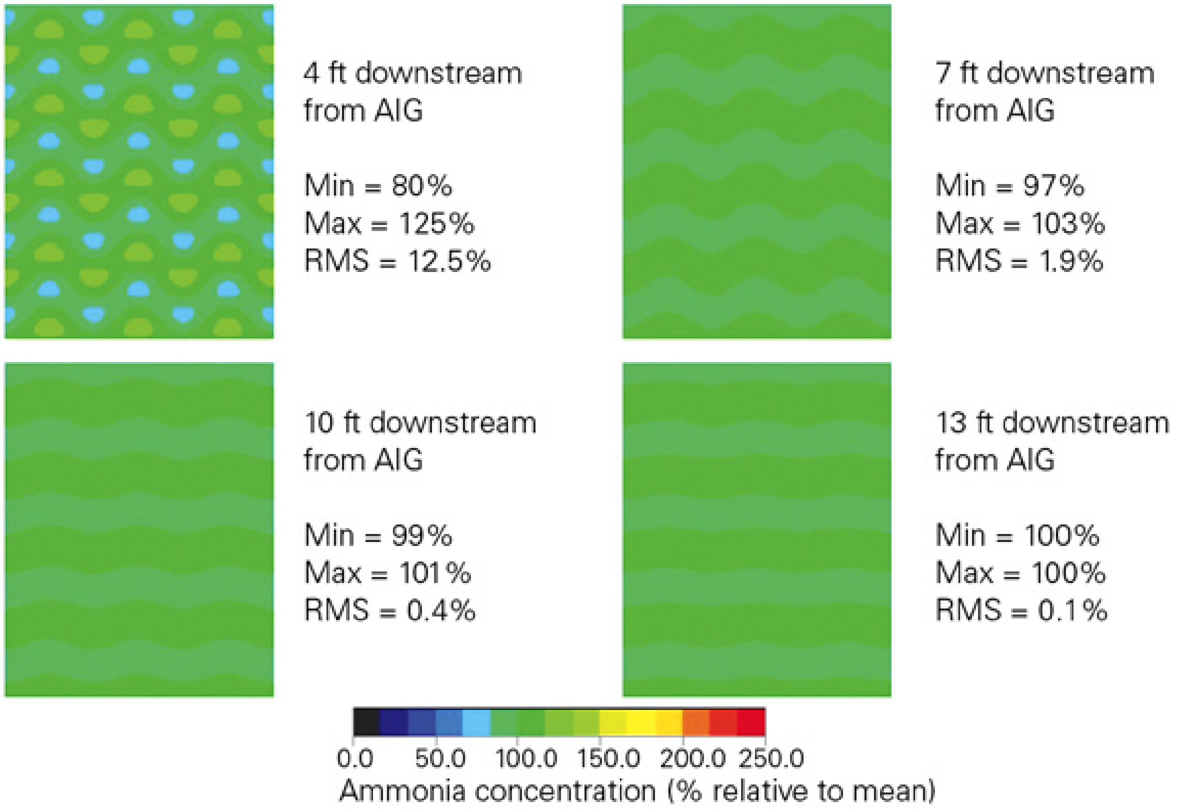
A computational fluid dynamic (CFD) study was conducted to both quantify the existing ammonia:NO_x distribution within the SCR reactor and to assess the potential design improvements. The existing AIG system consisted of 11 two-pronged lances designed with 22 single, 3/16-inch-diameter injection holes orientated to direct ammonia parallel to the flue gas flow, aimed directly at the SCR catalyst inlet.

Figure 5 illustrates the baseline ammonia distribution within the flue gas stream as predicted by the CFD analysis. The three panels show the ammonia mixing as it approaches the SCR catalyst—the gas flow is perpendicular to the page with each panel located downstream of the ammonia grid as indicated. This modeling indicates significant nonhomogeneity of ammonia in the flue gas at the SCR catalyst inlet. The original AIG design produced stratification, providing a ribbon-like effect where ammonia mixing was limited.



5. Out with the old AIG. CFD analysis of the existing ammonia injection grid found significant nonhomogeneity of ammonia in the flue gas at the SCR catalyst inlet. This stratification is seen by the ribbon-like effect (from front to back of the catalyst), where ammonia mixing was limited. Shown in the figure is the relative ammonia concentration in the flue gas. Each figure is a cross-section of the flue gas path measured downstream from the AIG. Source: Cormetech

The CFD model was then modified to incorporate improvements designed to optimize mixing by changing AIG parameters such as nozzle spacing, nozzle diameters, and spacing between lances. Figure 6 shows the predicted ammonia distribution for the improved design. The figure shows that the stratification has been eliminated and that the ammonia distribution at the SCR catalyst inlet was substantially improved.

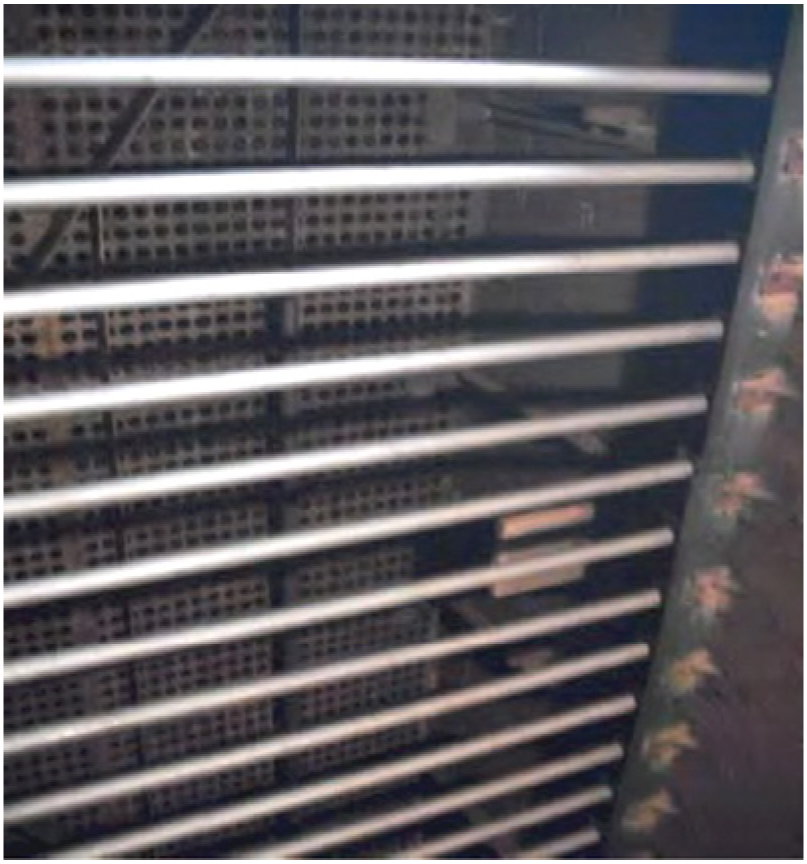


6. In with a new AIG. The CFD models found that a modified AIG design would significantly improve mixing of the flue gas with ammonia. The results found that the stratification (Figure 5) was eliminated and that the ammonia distribution at the SCR catalyst inlet was substantially improved. Source: Cormetech

Phase III: Catalyst Replacement and Optimization

As a result of the successful process modeling, recommendations were made for replacing the existing two-prong design AIG (Figure 7) with a three-prong design, as shown in Figure 8. The new lances also employed an optimized nozzle pattern and size. Cormetech also designed new sidewall baffles to eliminate bypass of untreated flue gas along the reactor sidewalls. These design recommendations were accepted by SHEC. The proposed modifications were installed on a single combustion turbine, Unit 3, to test and confirm the benefits of these changes.

7. Out with the two-prong lance. The original ammonia injection grid used two lances attached to a single ammonia supply header, a “two-pronged” design (Figure 2). Courtesy: Cormetech



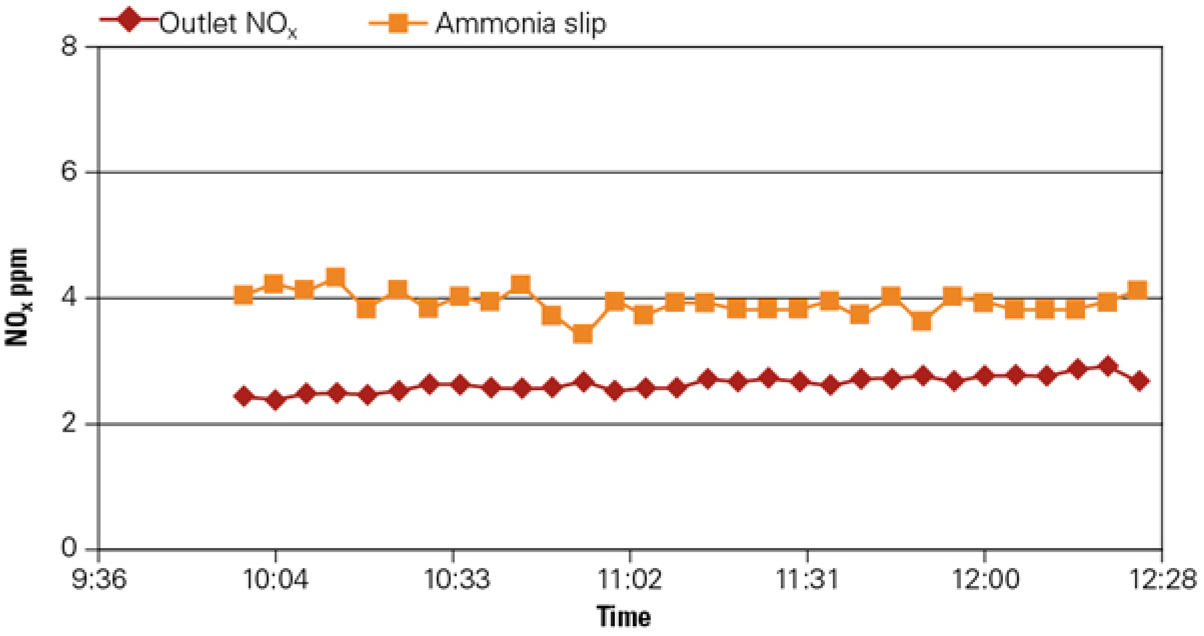
8. In with a three-prong lance. The new “three-prong” design added an additional AIG lance on each header where two had been used previously (Figure 7). Sidewall baffles were also added to improve ammonia mixing with the flue gas. Courtesy: Cormetech

As a final step prior to implementation of the modeled changes, Cormetech first performed full-load NO_x reduction baseline testing. A test plan was developed to operate Unit 3 at full load and perform sampling across the duct cross section. The flue gas characterization was completed through a series of sampling measurements taken across the duct (side to side) and repeated at different elevations (vertically). The goal was to access the effective ammonia:NO_x molar ratio distribution, which is a key input parameter to a successful SCR when operating at high efficiency and low ammonia slip. Testing before modifications revealed, as suspected, a poor ammonia:NO_x distribution of approximately 30% RMS, further verifying the CFD model result and field observations.

Unit 3 was then modified during the site’s planned fall maintenance outage. The AIG lances were replaced and sidewall baffles were installed. Two weeks after the outage was completed, flue gas testing was repeated. Results showed a significant ammonia:NO_x distribution improvement from the original 30% RMS to 7% RMS. The improvements to the ammonia injection system are estimated to save more than 11% in the annual operating costs for aqueous ammonia. Further, the improved ammonia:NO_x distribution will effectively extend the operating life of the SCR catalyst by allowing the margin previously needed to compensate for poor distribution to be used to compensate for catalyst deterioration over time.

Given the successful evaluation of the improved system, similar changes were made on the remaining three units during the regularly scheduled spring 2009 outage.

With the new high-performance catalyst and ammonia injection modifications complete, performance tests were conducted under full load and at design conditions (2.5 ppm outlet NO_x). Operational testing confirmed outlet NOx levels trended at 2.5 ppm and the ammonia slip remained below 5 ppm, meeting all performance guarantees (Figure 9).



9. Under the limit. Unit 3 performance test results with the new catalyst and AIG modification at full load are illustrated. Testing confirmed outlet NOx levels trending at 2.5 ppm and the ammonia slip remained below 5 ppm meeting all performance guarantees. Source: Cormetech

Following 2,660 hours of operation, the activity of the high-performance SCR catalyst continues to be exceptional, with NO_x reductions exceeding 92% at 5 ppm ammonia slip, showing no degradation in performance from the new condition. A second catalyst test is scheduled after approximately 5,000 hours of operation.

—Terry McTernan, PE (mcternanht@cormetech.com) is manager of project management for Cormetech.

EXHIBIT 2

MITSUBISHI
POWER SYSTEMS

100 Colonial Center Parkway
Lake Mary, FL 32746 USA
Tel 407.688.6100
Fax 407.688.6481

December 18, 2013

Subject: Hot SCR Systems for Combustion Turbines in Simple Cycle

SCR systems are commonly utilized on combustion turbines in simple cycle power generation as shown by the number of installations on the exhausts of GE, Pratt & Whitney and Rolls Royce aero derivative combustion turbines. These units typically have exhaust gas temperatures below 900F and have hot SCR systems installed both with and without tempering air systems applied. Successful NOx catalyst experience at temperatures ranging from 850F to 900F exists for many units installed with Cormetech and Haldor Topsoe catalyst. Tempering air has often been applied to bring the bulk exhaust temperatures down to 750F to allow the usage of the most efficient NOx catalyst. The cost of supplying the tempering air system offsets the cost of supplying a higher temperature catalyst that is slightly less efficient than the standard catalyst available for 750F operation.

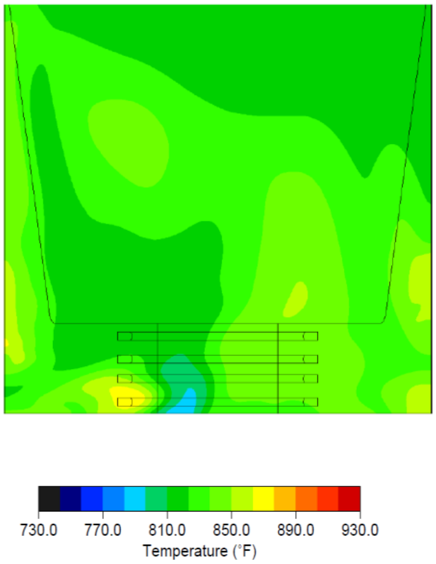
Hot SCR for F Class simple cycle installations has a bad reputation due to installations with improper application of an unproven high temperature catalyst and poor exhaust ducting design although Mitsubishi has had prior success with hot SCR systems for Frame CTs at SMUD, TEPCO Yokosuka and our K Point facility in Japan, as did Applied Utility Systems at MID McClure. Inspection of the hot SCR systems in the Riverside units installed behind Siemens 501FD2 combustion turbines and the SMUD unit installed behind a GE 7EA combustion turbine showed results typical to the installations of these early Frame CT SCR applications; NOx catalyst active coating was flaking off due to differential thermal growth issues between the active wash coat and the ceramic substrate and high temperature indications inside the unit showing poor tempering air distribution or inadequate tempering air volume. There were also indications of design issues with the ammonia distribution system. Successful designs for F Class and larger combustion turbines must overcome these issues as the exhaust temperatures are now exceeding 1200F.

Cormetech and Haldor Topsoe, among other catalyst companies, provide catalyst for simple cycle applications and have excellent installation records for units operating with bulk flue gas temperatures of 750F, 800F and 850F up to 900F. These catalyst companies provide catalyst that is homogenous and is not susceptible to thermal growth issues like those that caused the early catalyst to fail due to loss of the active catalyst layer that was applied as a wash coat.

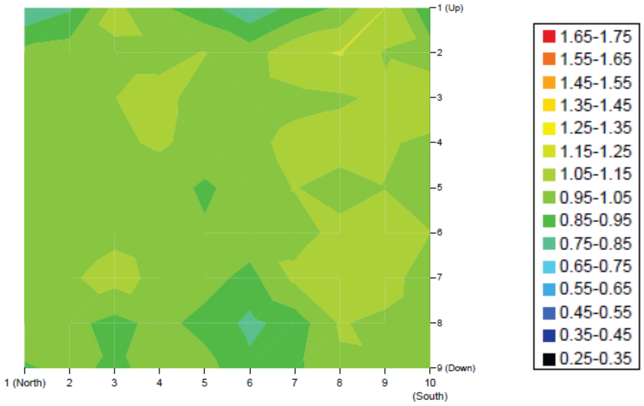
As indicated by the numerous successful SCR installations for aero derivative combustion turbines, high temperature SCR design for F Class can be accomplished by limiting the bulk flue gas temperature to a level supported by the current catalyst operating temperatures with a reasonable safety margin in the temperature distribution across the face of the catalyst bank to allow for less than perfect mixing of the tempering air to the combustion turbine exhaust. As shown in 850F to 900F combustion turbine exhausts, hot SCR is not only achievable, but very successful in application.

Our success at Marsh Landing is based on properly evaluating the exhaust gas design conditions and designing a tempering air mixing system that provides an exhaust gas bulk inlet temperature to the NOx catalyst at a level that protects the catalyst from heat degradation and within a differential temperature across the catalyst that is acceptable for maximum NOx removal efficiency for the selected catalyst. The design is robust and provides proper temperature mixing across the operating range of the F Class CT. The design goal at Marsh Landing was to provide a bulk exhaust temperature, with a profile of +/- 60F, with an acceptable design margin below the maximum continuous operating temperature of the selected Cormetech catalyst.

Marsh Landing Generating Station



Temperature Profile



Normalized Velocity Profile

We achieved the design criteria goals for temperature as well as velocity distribution of <10% RMS across the NOx catalyst and NH_3 to NOx molar ratio maldistribution of <10% RMS across the NOx catalyst; meeting all of our design goals.

The CFD (Computational Fluid Dynamics) modeling was validated through the use of a physical cold flow model. Results of the cold flow modeling provided greater than 95% correlation with the CFD model and provided verification of our design. The indicated results of the modeling effort were substantiated during field testing of the installed units at Marsh Landing.

SCR NOx reduction technology has demonstrated greater than 95% reduction of NOx in exhaust gases in industrial and power installations. Mitsubishi has previously guaranteed NOx reduction efficiencies of 96% and have predicted reduction efficiencies of 98% and achieved these levels in refinery and power applications. The SCRs at Marsh Landing were designed with a reduction efficiency of 90% while in transient operation and 72% at steady state operation.

NOx reduction of combustion turbine exhausts from levels above 42 ppm to current permit levels at 2ppm has been achieved across the industry and these levels are even more common today. Successfully reducing NOx with 95% removal efficiency requires not only good temperature distribution of the exhaust gas across the face of the catalyst, but also good velocity distribution and effectively mixing the ammonia into the exhaust gas to ensure that the NH_3 to NOx molar ratio maldistribution falls within the NOx catalyst manufacturer's design requirements. These levels of NOx reduction are commonplace for hot SCR systems and are easily achievable for F Class combustion turbine exhausts with good engineering design.

NOx reduction for ultra-low sulfur diesel fuel (ULSD) has been proven to be as successful as NOx reduction for units firing natural gas. The higher NOx levels of the exhaust gas from the combustion turbines firing ULSD requires additional catalyst and increased ammonia demand over those firing natural gas, but otherwise design follows existing parameters. The SCR system can be designed to maintain emissions compliance during the changeover of fuels from natural gas to ULSD when the NOx and CO emissions levels will increase during the change.

Since the SCR system will be sized for the higher removal efficiency required to reduce the NOx emissions from 42 ppm while the CT is firing ULSD, the system has the catalyst and ammonia capacity to handle the tripling of NOx emissions during the change. This requires good control methodology to anticipate the emission level changes and match the SCR performance to the CT exhaust conditions.

Permit levels for ammonia slip have also been declining; first to levels of 10 ppm and now to levels of 5 ppm. Ammonia slip levels of 5 ppm are now more common throughout industry and are achievable as demonstrated in many systems. Guaranteed ammonia slip levels of 5 ppm for five years for peaking plants utilizing simple cycle technology are being offered today by all SCR and NOx catalyst manufacturers. Proper design of the SCR flow path, knowledge of the combustion turbine exhaust criteria and catalyst volume make this level of guarantee achievable.

Peaking power plants that require high load demand ramp rates, such as Marsh Landing, require additional design consideration in design, catalyst volume and control technology. Control system design is of greatest concern in controlling the sudden increase in NOx production from the combustion turbine when quickly changing load at higher than normal ramp rates and consideration must be give catalyst volume, predicting NOx performance and quickly meeting the ammonia demand requirements. The combustion turbines may need to be specifically tuned to outlet NOx levels that are more stable across all loads and ramp rates to allow for high NOx reduction efficiencies and low ammonia slip levels that are current requirements. The combustion turbine manufacturer and the SCR manufacturer must work closely together to develop an integrated control methodology to ensure that all environmental requirements are met while meeting all power production needs effectively.

Mitsubishi firmly believes that SCR systems for large Frame gas turbines are commercially and technologically viable. This is based on the success of NOx reduction for the aero derivative market and successfully designing the hot SCR system at Marsh Landing to achieve similar design conditions at the NOx catalyst as found in these successful installations. We are actively involved in bidding and pursuing additional SCR projects for large Frame gas turbines, including GE 7FA, Siemens 5000F and Mitsubishi GAC and JAC combustion turbines.

For further information, please contact:

Rand Drake
General Manager, SCR Systems
Mitsubishi Power Systems Americas, Inc.
(407) 688-6414

EXHIBIT 3

SCR DeNOx System Presentation for NYISO

A short overview of Emission Control Systems for Gas Tubines

Rand Drake, General Manager & Bob McGinty, Sr. Manager, Business Development

MITSUBISHI POWER SYSTEMS

PRESENTATION OVERVIEW

COMPANY HISTORY& QUALIFICATIONS

SCR SYSTEM DESIGN CONSIDERATIONS
SCR & CO/VOC CATALYST
REACTOR MODELING-CFD & ISOTHERMAL
SCR SYSTEM CONSTRUCTABILITY
AMMONIA SYSTEMS-AQUEOUS, ANHYDROUS

MITSUBISHI
POWER SYSTEMS

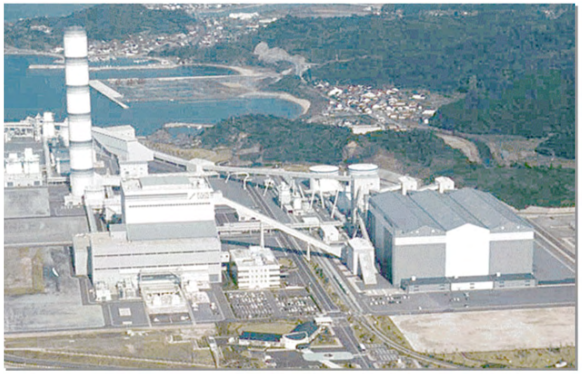
MPSA COMPANY HISTORY & QUALIFICATIONS

MITSUBISHI
POWER SYSTEMS

MITSUBISHI HEAVY INDUSTRIES, LTD.

Energy Sector – Power Systems Division


Combined Cycle Power Plant

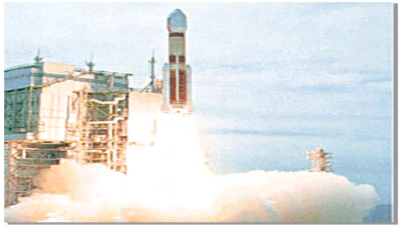

Conventional Thermal Power Plant


IGCC


Ship & Ocean

Aircraft


Infrastructure


Aerospace


Living & Leisure


Construction Machinery

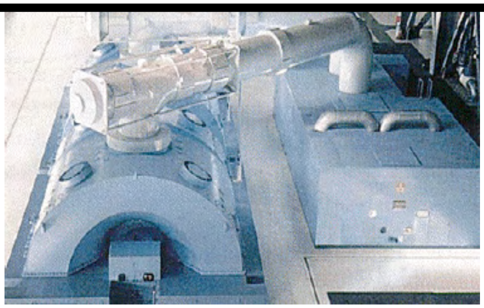

Transportation

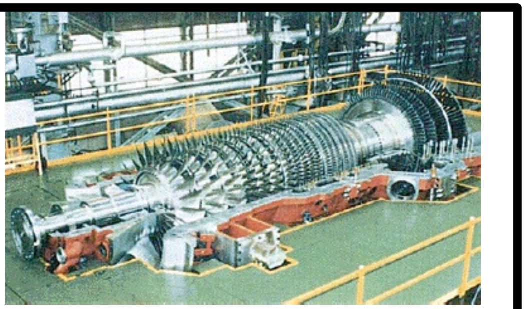

Industrial Machinery (FGD)

MITSUBISHI
POWER SYSTEMS

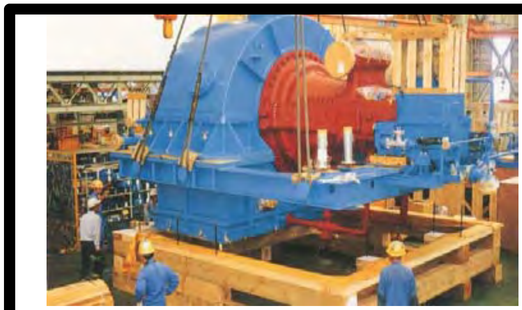
MHI, YOUR PARTNER IN POWER GENERATION DEVELOPMENT

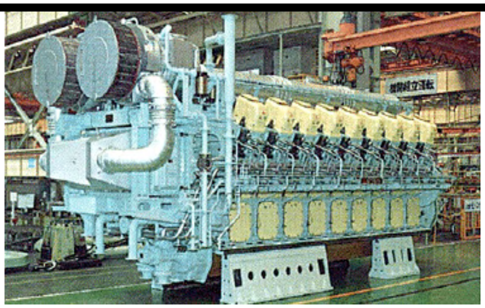

Combined Cycle Power Plant


Large Steam Turbine


Gas Turbine


Geothermal Power Plant


Small / Medium Steam Turbine


Reciprocating Power Plant


Wind Turbine


IGCC


ExxonMobil Torrance - 2000

SCR DeNOx Systems
Refinery Process Heaters,
Gas Turbines & Coal Fired Boilers

MITSUBISHI
POWER SYSTEMS

MITSUBISHI HEAVY INDUSTRIES

- Founded 1884, Headquarters – Tokyo, Japan
- 1969 Merger of three heavy industries – MHI Ltd.
  - 1979 Formed MHIA - US Headquarters New York, NY
  - 2001 Formed MPS – US Headquarters Lake Mary, FL
  - 2006 Name changed to MPSA

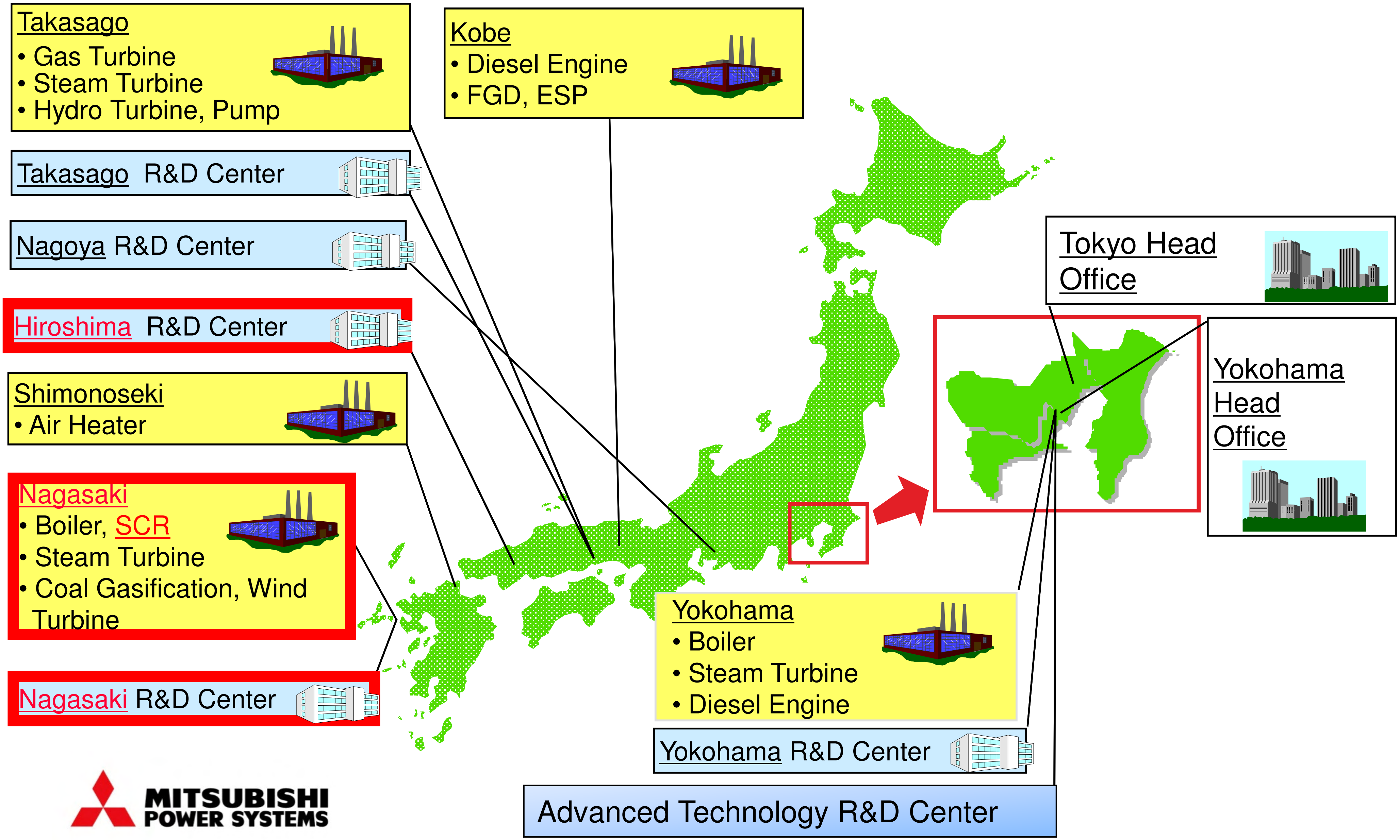
- Global Manufacturer:
  - Shipbuilding & Ocean Development
  - Power systems – Thermal, Renewable, Nuclear
  - Machinery & Steel Structures – Environment, Transportation, Medical, Industrial
  - Aerospace – Space Systems, Aviation
  - General Machinery & Special Vehicles
  - Other – Air Conditioners, Industrial Machine Tools

- 34,000 Employees manufacturing 700 products worldwide
- Sales in excess of $31 billion USD
- A “Mitsubishi Group” core company ~ $245 billion USD

MITSUBISHI
POWER SYSTEMS

MITSUBISHI HEAVY INDUSTRIES (MHI)

FACTORIES FOR POWER PLANT EQUIPMENT AND R&D CENTERS



Takasago
- Gas Turbine
- Steam Turbine
- Hydro Turbine, Pump

Takasago R&D Center

Nagoya R&D Center

Hiroshima R&D Center

Shimonoseki
- Air Heater

Nagasaki
- Boiler, SCR
- Steam Turbine
- Coal Gasification, Wind Turbine

Nagasaki R&D Center

Kobe
- Diesel Engine
- FGD, ESP

Tokyo Head Office

Yokohama Head Office

Yokohama
- Boiler
- Steam Turbine
- Diesel Engine

Yokohama R&D Center

Advanced Technology R&D Center

MITSUBISHI
POWER SYSTEMS

MPSA NORTH AMERICAN LOCATIONS

Regional Sales Offices

Sacramento
Chicago
Montvale
Tulsa
Toronto
San Juan
Houston
Denver

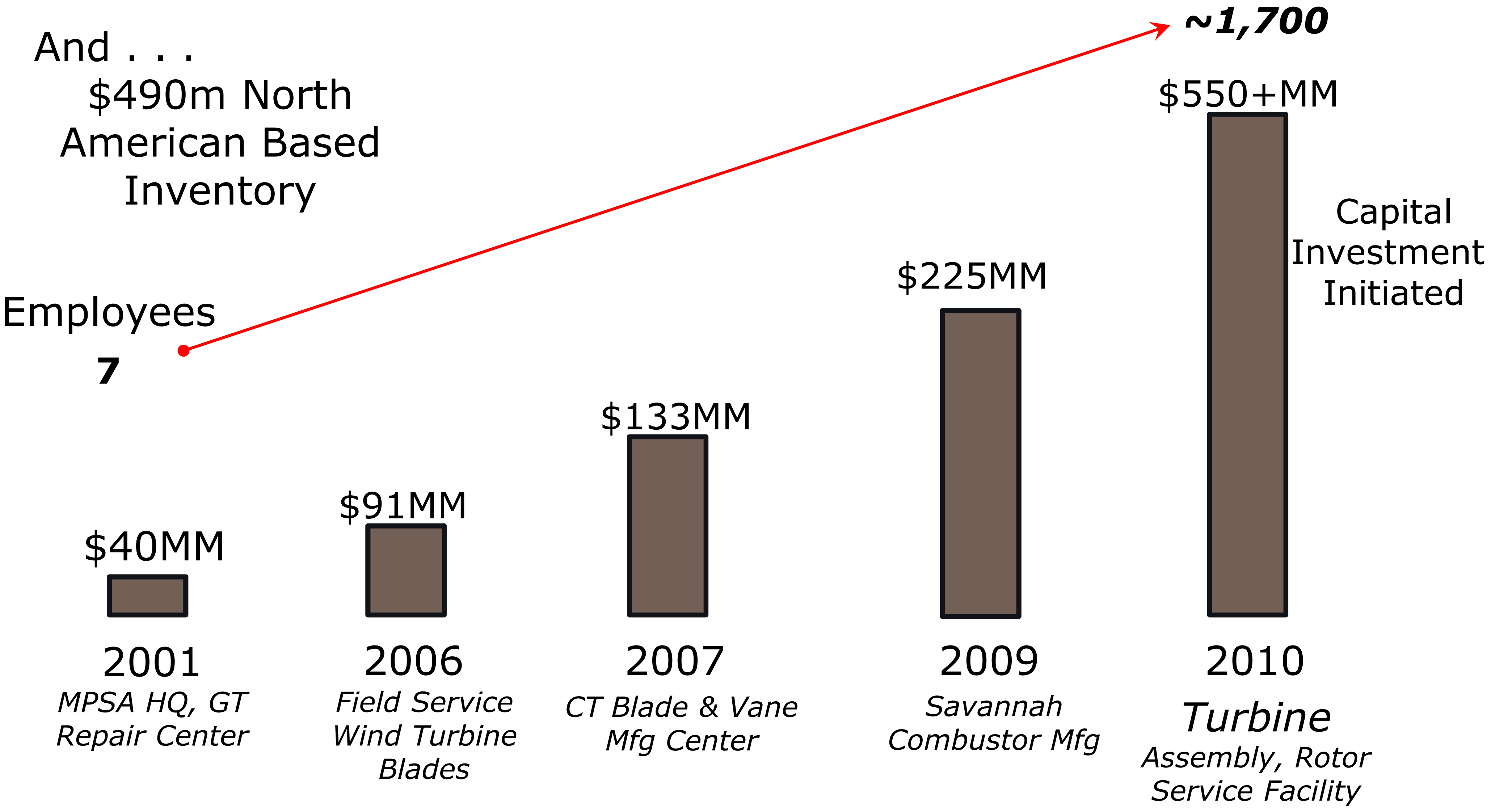
Strategic Partnerships & Alliances

PWPS
CORMETECH
ADVATECH

MITSUBISHI POWER SYSTEMS

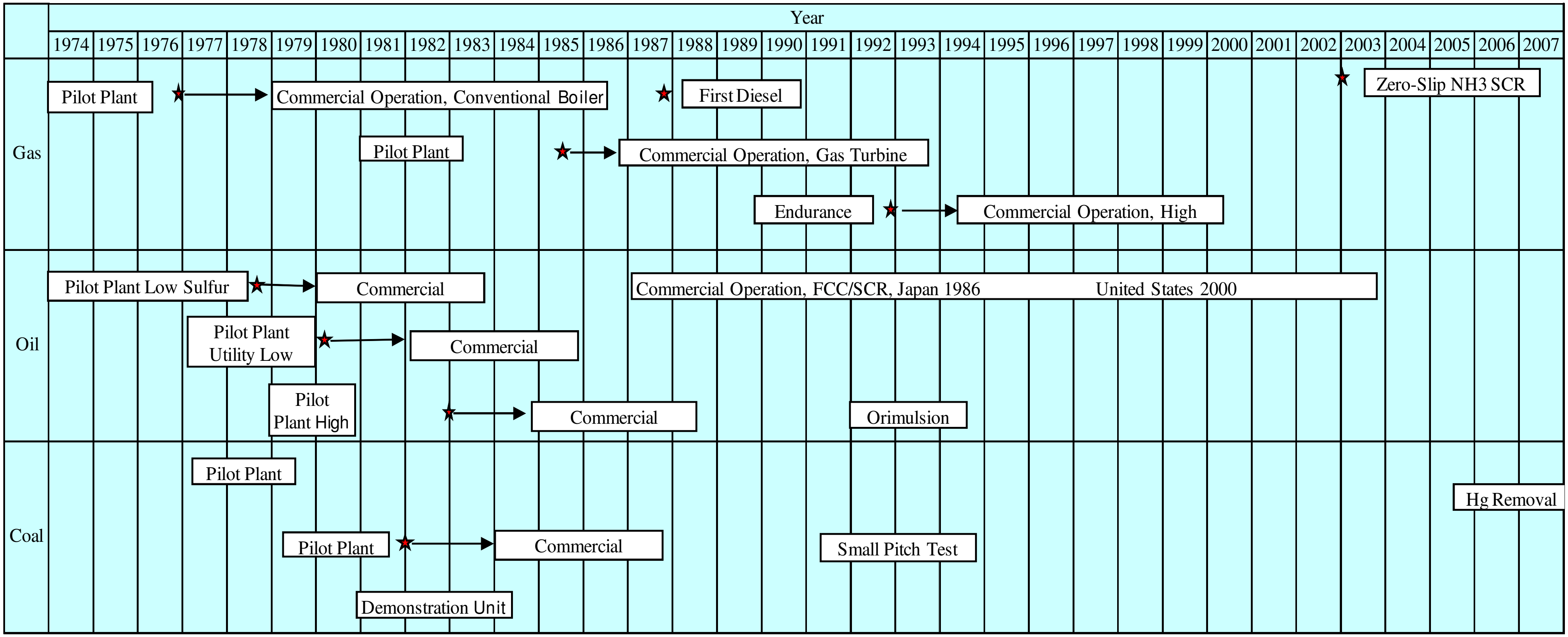
MPSA North American Commitment

And . . .
$490m North American Based Inventory



MITSUBISHI POWER SYSTEMS

DEVELOPMENT HISTORY (MITSUBISHI SCR)



Year

1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007

Gas

Pilot Plant → Commercial Operation, Conventional Boiler

First Diesel

Zero-Slip NH3 SCR

Pilot Plant → Commercial Operation, Gas Turbine

Endurance → Commercial Operation, High

Oil

Pilot Plant Low Sulfur → Commercial

Commercial Operation, FCC/SCR, Japan 1986 United States 2000

Pilot Plant Utility Low → Commercial

Pilot Plant High → Commercial

Orimulsion

Coal

Pilot Plant

Hg Removal

Pilot Plant → Commercial

Small Pitch Test

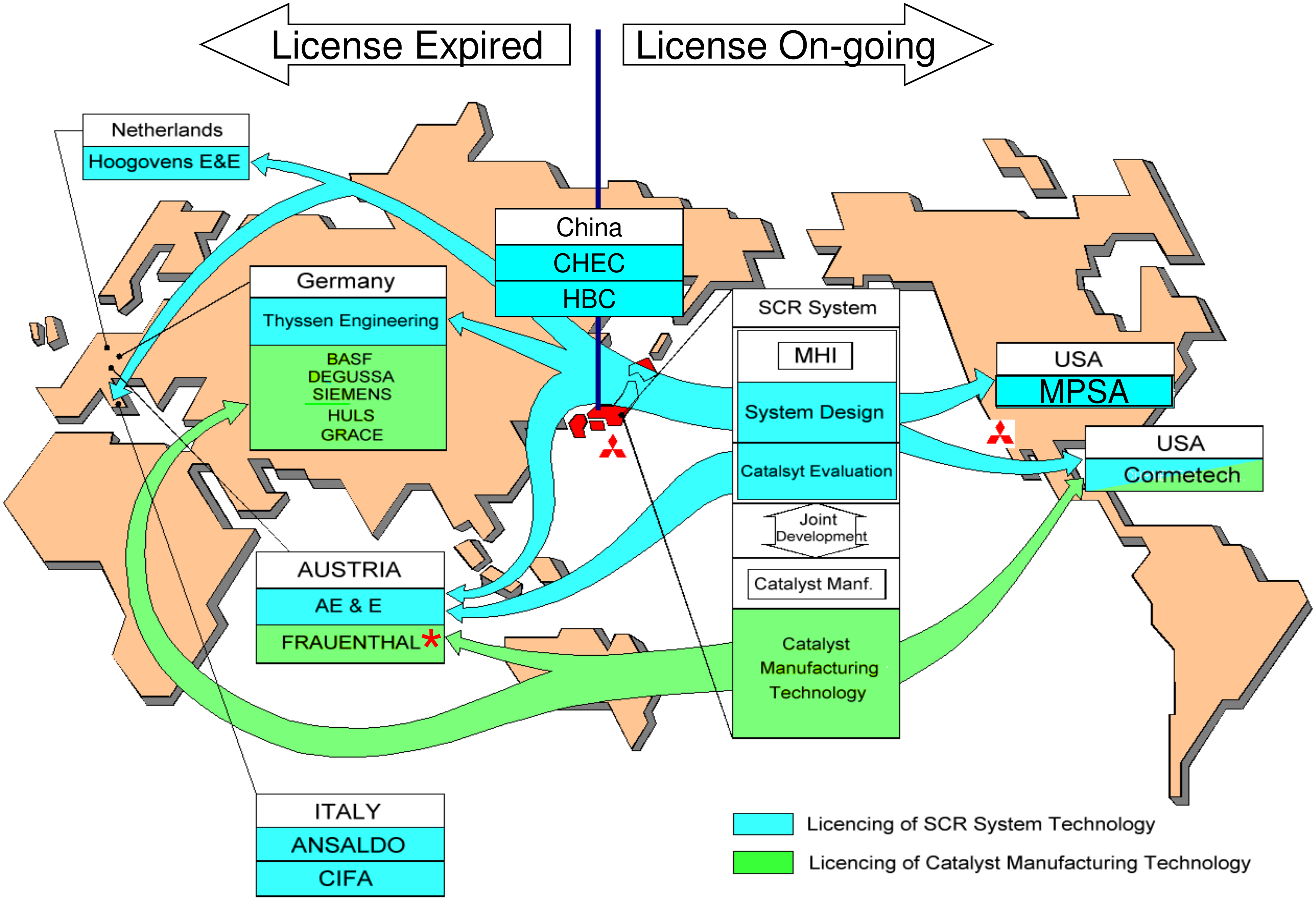
Demonstration Unit

MHIA & Cormetech Est'd

40 years of first hand experience.

MITSUBISHI POWER SYSTEMS

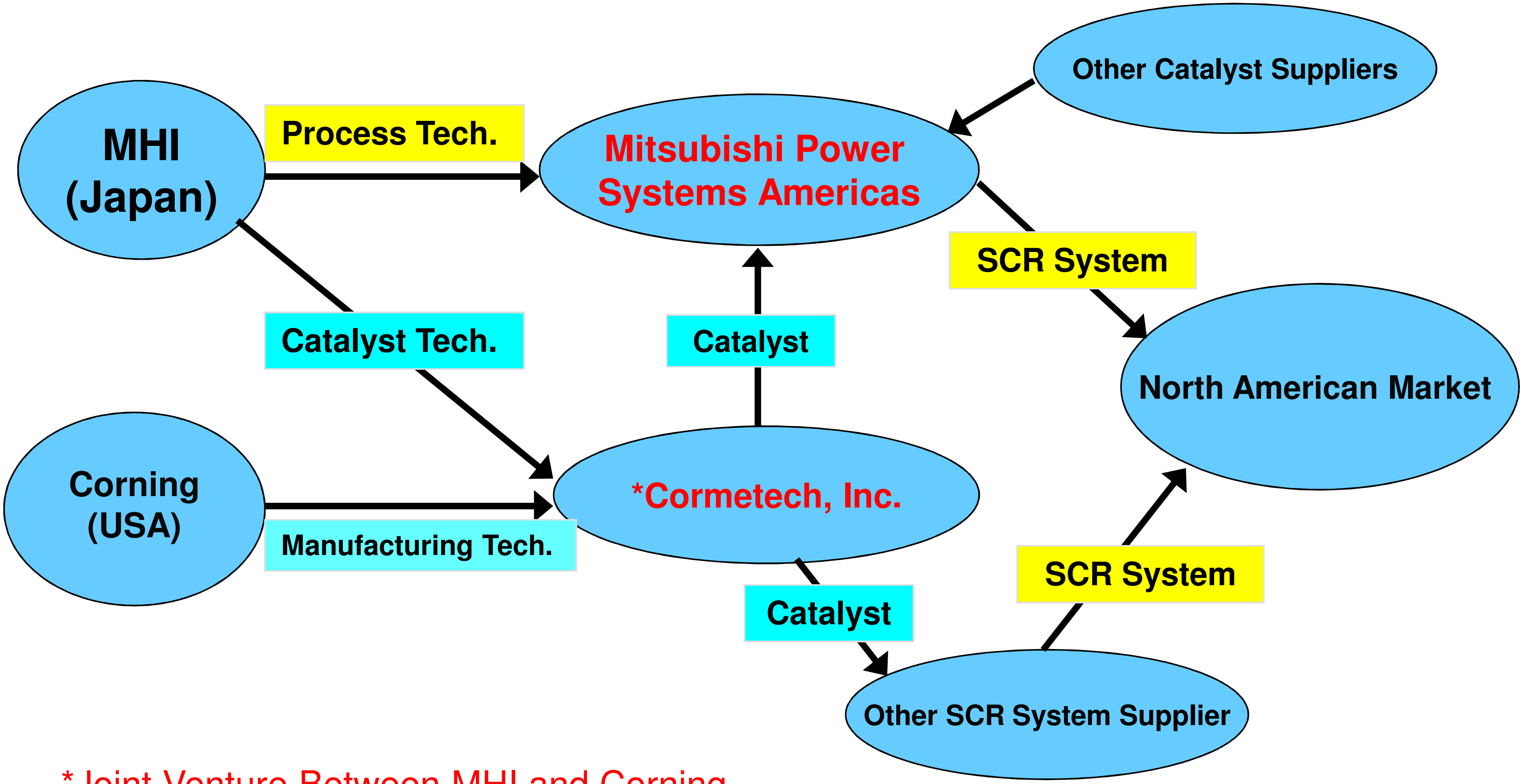
MITSUBISHI WORLD WIDE LICENSING



MITSUBISHI POWER SYSTEMS

* Frauenthal now operates as Ceram after licensing agreement expired

MITSUBISHI / CORMETECH RELATIONSHIP
(DIRECT/HANDS ON APPROACH)



MHI (Japan)

Process Tech.

Mitsubishi Power Systems Americas

Other Catalyst Suppliers

SCR System

Catalyst Tech.

Catalyst

North American Market

Corning (USA)

*Cormetech, Inc.

Manufacturing Tech.

SCR System

Catalyst

Other SCR System Supplier

*Joint Venture Between MHI and Corning

MITSUBISHI POWER SYSTEMS

WHAT MITSUBISHI OFFERS

- ‘Knowledge’ and ‘Expertise’ built over the past 40 years. (Original pioneer of SCR technology)
- Have successfully completed the most difficult and challenging projects.
  - High efficiency systems (NOx 2ppm / NH3 2ppm)
  - Zero-Slip systems
  - High temperature systems
  - Direct ammonia injection system
  - Largest systems supplier to FCCU
- Proven track record. (translates to *Low Risk*)
  - Have always met or exceeded performance guarantees
  - We do not walk away
- Very competitive, Supply highly reliable systems
- Experienced team in Lake Mary, FL & Newport Beach, CA
- Financial stability

ExxonMobil Torrance - 2000

MITSUBISHI
POWER SYSTEMS

MPSA EXPERIENCED TEAM

- US based team drawing on 40 years R&D in Japan and US

- MPSA Capabilities: Large Experienced Engineering Staff
  - SCR process design
  - Feasibility study and detailed engineering (*incl. 3D*)
  - Project execution / management
    - Fabrication in North America only (*sub-contract*)
    - Shop preassembly of components (wherever possible) -> helps to minimize field changes and associated cost
  - CFD and Cold Flow Model Test (*designed and controlled by Mitsubishi / executed at local facilities*)
  - Quality control and inspection (*ISO 9001 Certified*)
  - Commissioning and start-up

MITSUBISHI
POWER SYSTEMS

MITSUBISHI SCR SUPPLY LIST

		Japan, Asia, North & South America
Boiler	Coal	52
	Oil	64
	Gas	42
Gas Turbine		245
Diesel Engine		153
FCC & Refinery Heater		49
Total Units Installed		608

SUCCESSFUL HIGH TEMP SCR UNITS

Project	K-point	SMUD McClellan	TEPCO Yokosuka	Carson IceGen	NRG Marsh Landing	MID McClure (AUS)
CT	M701F	Frame 7EA	M701DA	LM 6000	SGT6-5000F(4)	Frame MS7001B
Gas Temp	1112 degF	1020 degF	986 degF	875 degF	1146 degF	969 degF
DeNOx Eff.	86%	90%	60%	90%	87%	90%
Start of Operation	Jul.1992	Apr. 2004	Aug. 1992	June 1995	Apr 2013	Dec 2005
Operating Hours	3,000 hrs	450 hrs	4,081 hrs	17,000 hrs	1200 hrs	3600 hrs 844 on #2
Tempering Air Fan	Yes	No	No	No	Yes	Yes

SCR FOR SIMPLE CYCLE GT
(TOKYO ELECTRIC CO., YOKOSUKA, JAPAN)

Project Features

- M701DA combustion turbine
- Max operating temp: **986F**
- NOx Removal Ratio: 60%
- **No Tempering Air**
- Operating Hours: 4,081 hours
- Turnkey – Completion by Aug., 1992

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SCR FOR SIMPLE CYCLE GT
(SMUD McCLELLAN)

SCR Design Parameters

- GE 7E combustion turbine
- Max operating temp: 1,020F
- NOx Removal Ratio: 90%
- No Tempering Air
- Equipment Supply; Start up May 2004

SCR FOR SIMPLE CYCLE GT

MODESTO IRRIGATION DISTRICT

Project Features

- GE MS7001B Gas Turbine
- Natural Gas/ULSD
- Max operating temp: **975 F**
- NOx Removal Ratio: 90%
- w/ CO/VOC oxidation catalyst
- **w/Tempering Air**
- Dec, 2005.
- Frame F Class GT
- SCR System by AUS

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SCR FOR SIMPLE CYCLE GT (NRG MARSH LANDING)

Project Features

- SGT6-5000F combustion turbine
- Max operating temp: **1,146F**
- NOx Removal Ratio: 87%
- w/ CO/VOC oxidation catalyst
- **w/Tempering Air**
- COD May 1, 2013.

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SCR SYSTEM & CATALYST

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Principle of SCR Reaction

(Denitrification Process)

Catalyst

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

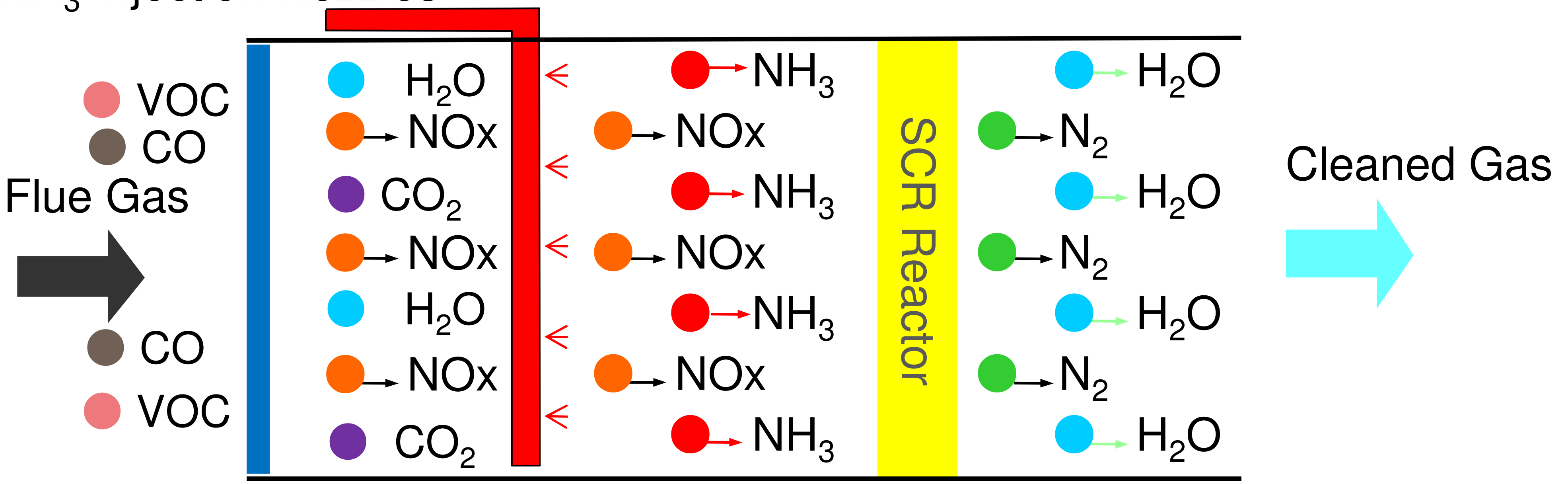
$$NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$$

Catalyst

$$2\,CO + O_2 \rightarrow 2CO_2$$

$$wVOC + xO_2 \rightarrow yCO_2 + zH_2O$$

NH_3 Injection Nozzles



VOC

CO

Flue Gas

CO

VOC

H_2O

NOx

CO_2

NOx

H_2O

NOx

CO_2

NH_3

NOx

NH_3

NOx

NH_3

NOx

NH_3

SCR Reactor

H_2O

N_2

H_2O

N_2

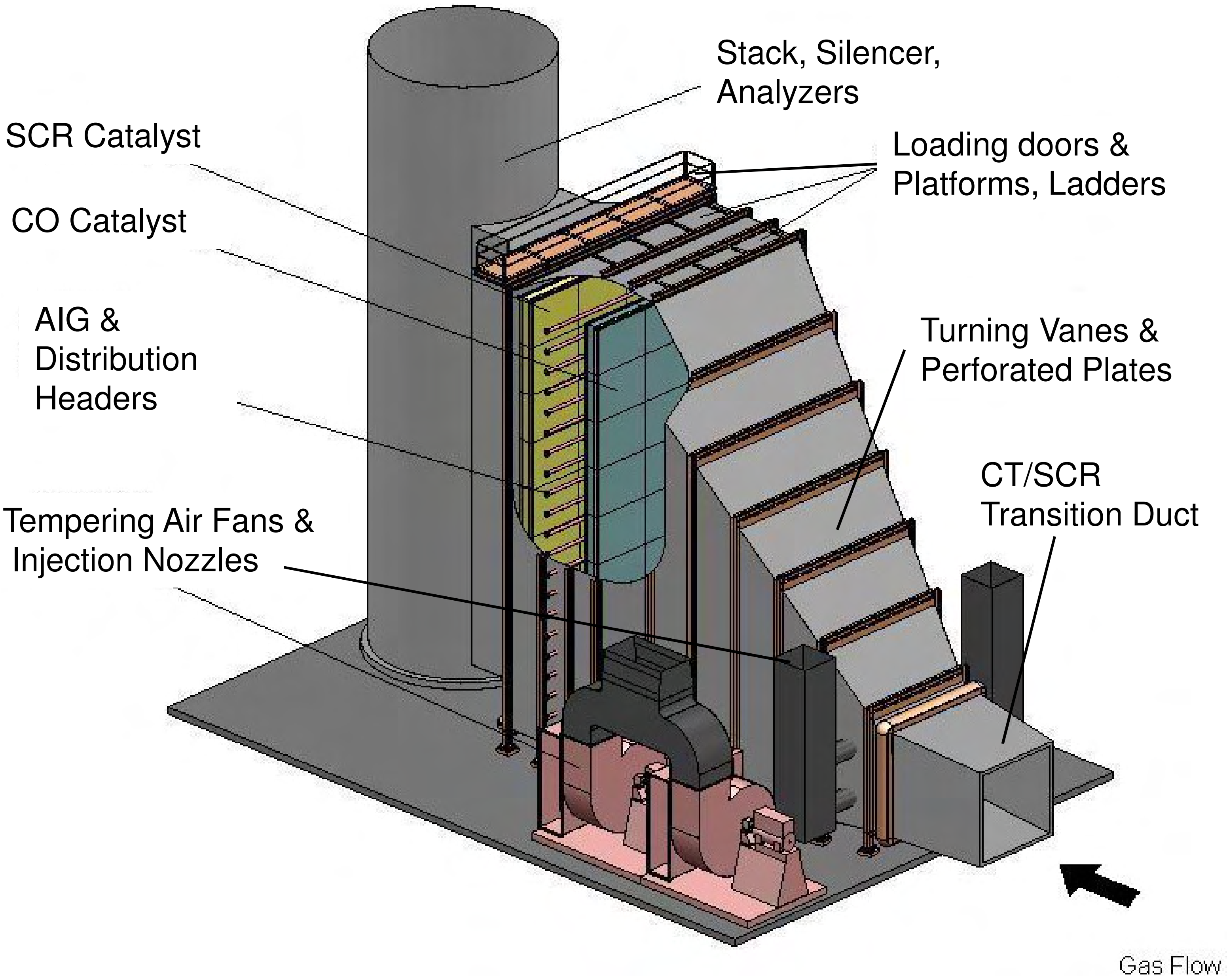
H_2O

N_2

H_2O

Cleaned Gas

SCR FOR SIMPLE CYCLE GT (TYPICAL SCOPE)

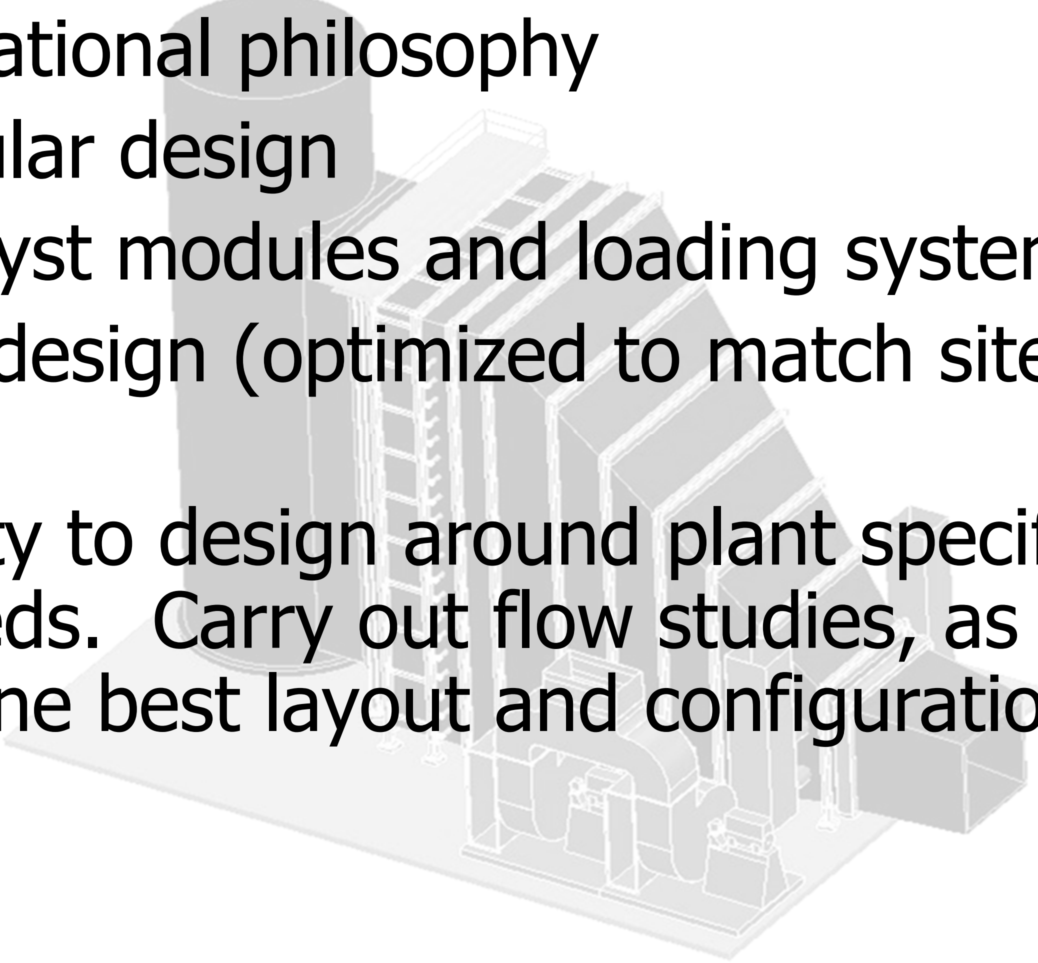


Add’l Scope
- AFCU
- PLC
- Tech Advisor
- Training

Options
- Ammonia Tank
- Pump Skid

Guarantee
- NOx; CO; VOC
- Utility
- dP
- Noise
- Catalyst Life

SCR SYSTEM DESIGN



- Standardized design
  - Operational philosophy
  - Modular design
  - Catalyst modules and loading system
  - Skid design (optimized to match site requirements)

- Flexibility to design around plant specific restrictions and needs. Carry out flow studies, as necessary, to determine best layout and configuration

SCR SYSTEM DESIGN

Design Considerations:

- Seismic and Wind Loads
- **Thermal Growth**
- **Catalyst Support & Sealing**
- Accessibility (Internal and external components)
- **Thermal Insulation & Liner System**
- Prefabrication – Modular - Panel - Semi Modular
- **Constructability – TIME & MONEY**
- Operation & Maintenance

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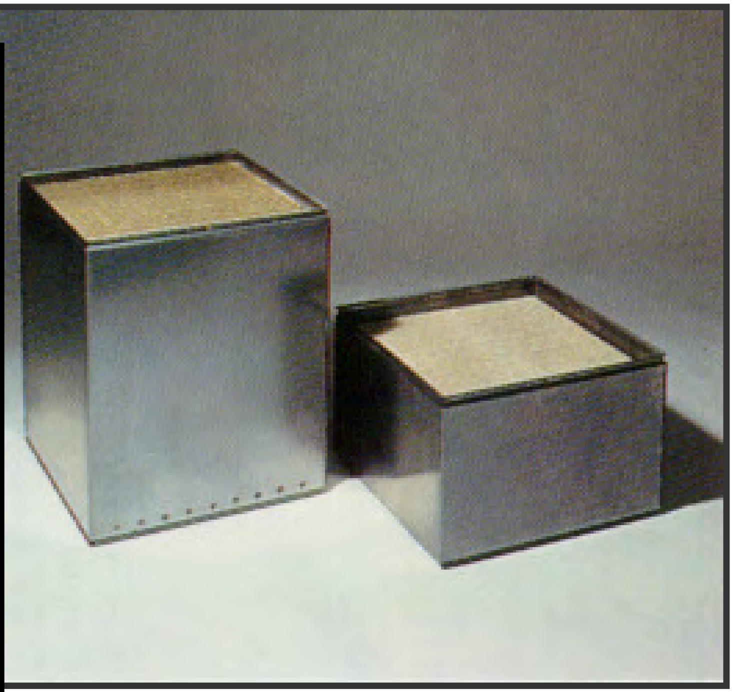
KEY CONSIDERATIONS FOR GAS TURBINES SCR

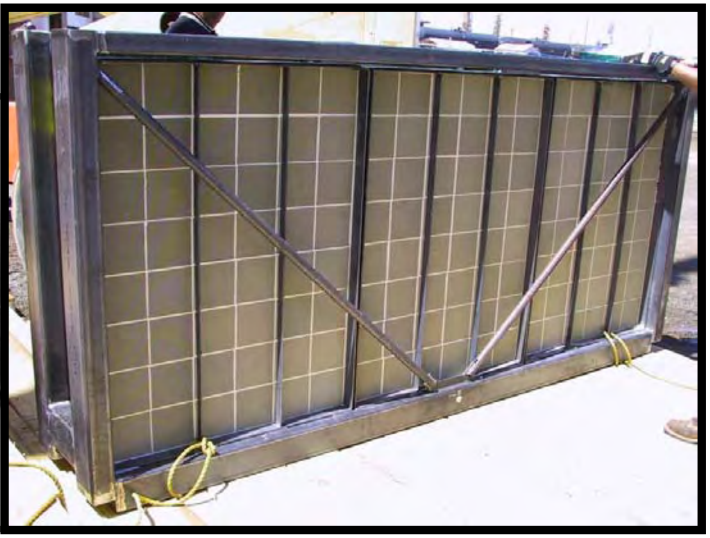
Service life – Hours & Years (customer requirement)	Ammonia slip
Exhaust gas temperature	Catalyst temperature
Turbine exhaust NO_X , CO, VOC levels	Reactor duct configuration
Required NO_X CO, VOC removal & stack exit	Flue gas flow/temperature distribution
Pressure loss allowance	SO2 to SO3 Conversion
Volumetric flow rate	NH_3/NO_X distribution

CATALYST MODULES & TEST COUPONS/BLOCKS



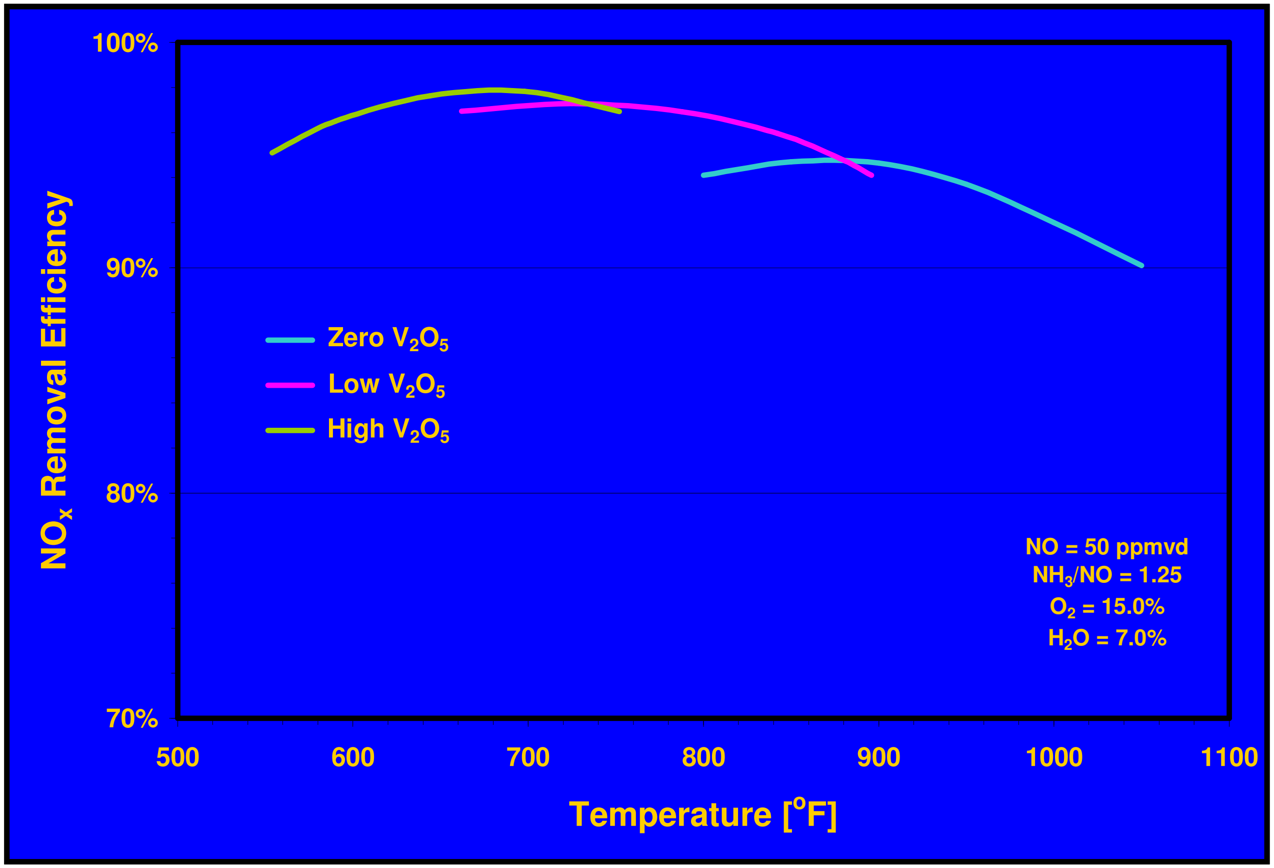
Typical Sampling Coupon

Typical Sampling Basket



CATALYST SELECTION: TEMPERATURE

Large operating temperature range (350 - 1100°F)



- High temp catalyst:
  900F ~ 1,100F
- Medium-high temp catalyst:
  800F ~ 900F
- Medium (Standard) catalyst:
  450F ~ 800F

At higher temperature,
reduce V:W ratio for
- Stronger NH3 adsorption
- Lower NH3 decomp rate
- Higher DeNOx rate
- Lower sintering rate

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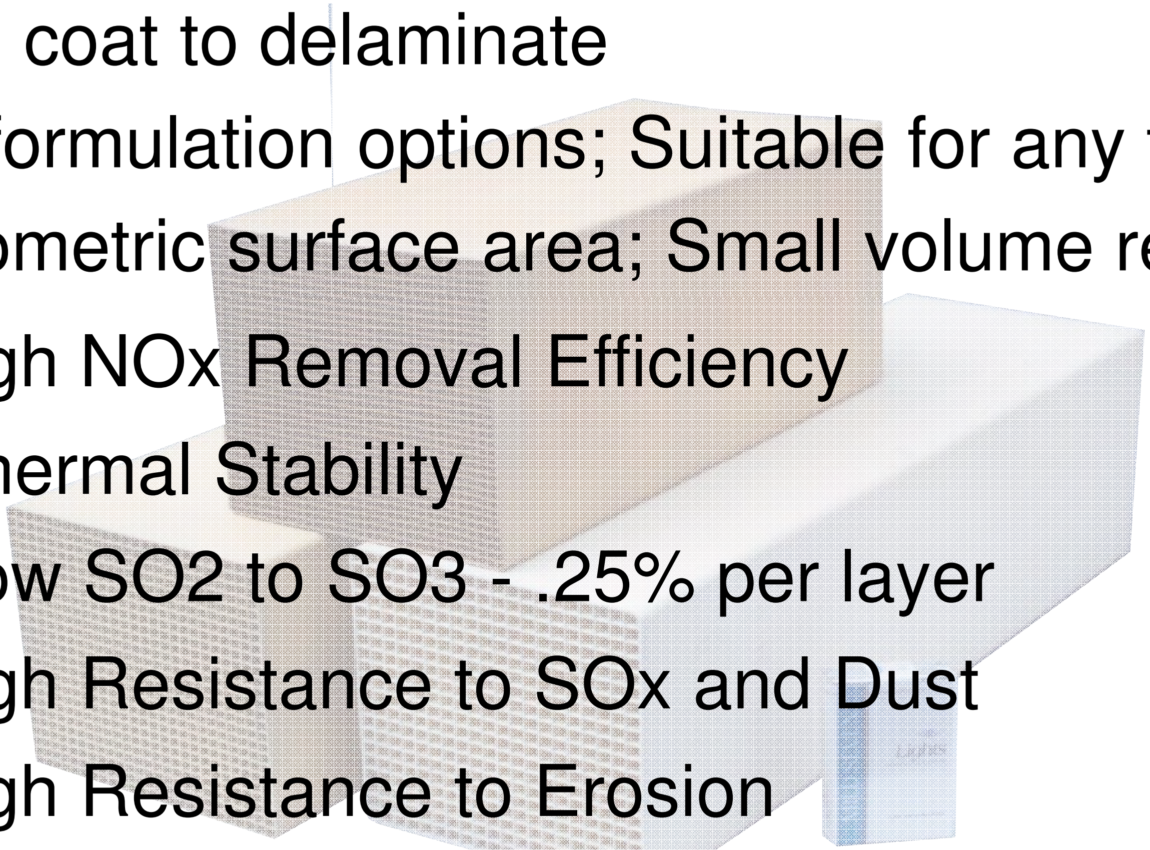
HONEYCOMB CERAMIC SCR CATALYST



- Ti-V-W based homogeneous grid type
- No wash coat to delaminate
- Various formulation options; Suitable for any type of fuel
- High geometric surface area; Small volume required
    1. High NOx Removal Efficiency
    2. Thermal Stability
    3. Low SO2 to SO3 - .25% per layer
    4. High Resistance to SOx and Dust
    5. High Resistance to Erosion
    6. Safe Treatment of Spent Catalyst

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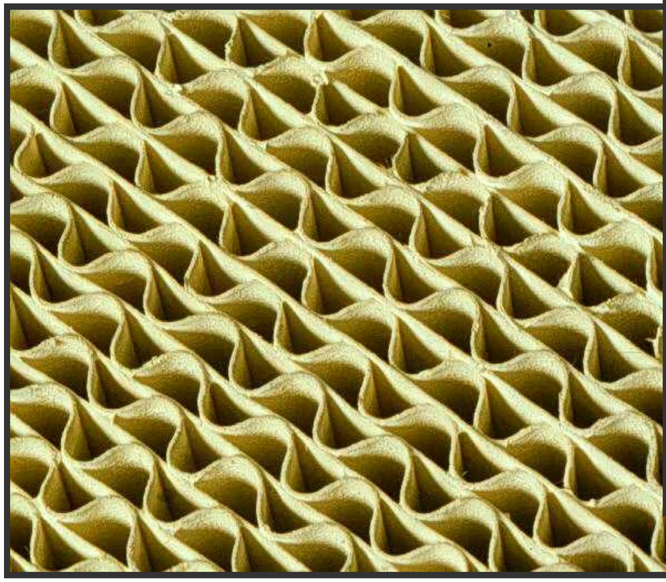
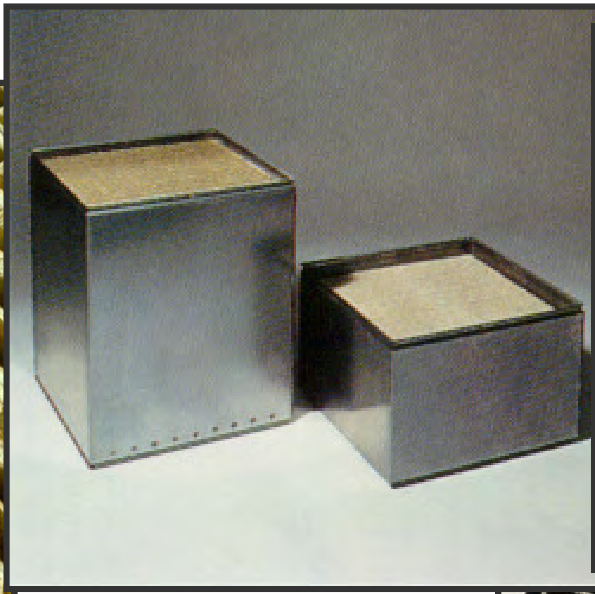
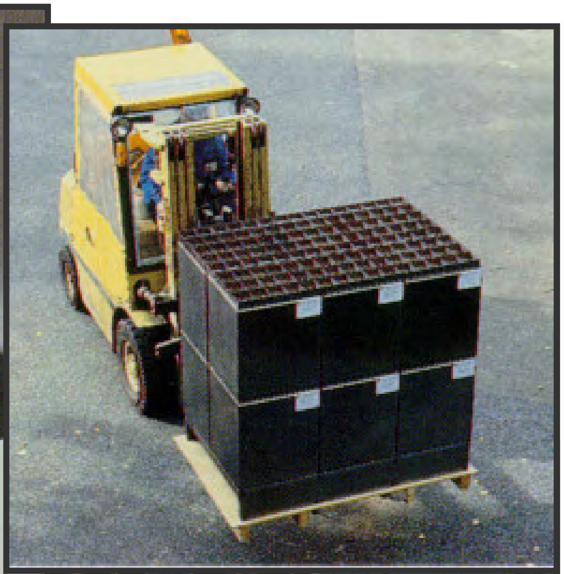
Corrugated - Type SCR Catalyst







- Surface area (CPSI & porosity)
- Active sites (reaction promotion)
- Diffusion controlled mass transfer
- Lite weight low pressure drop

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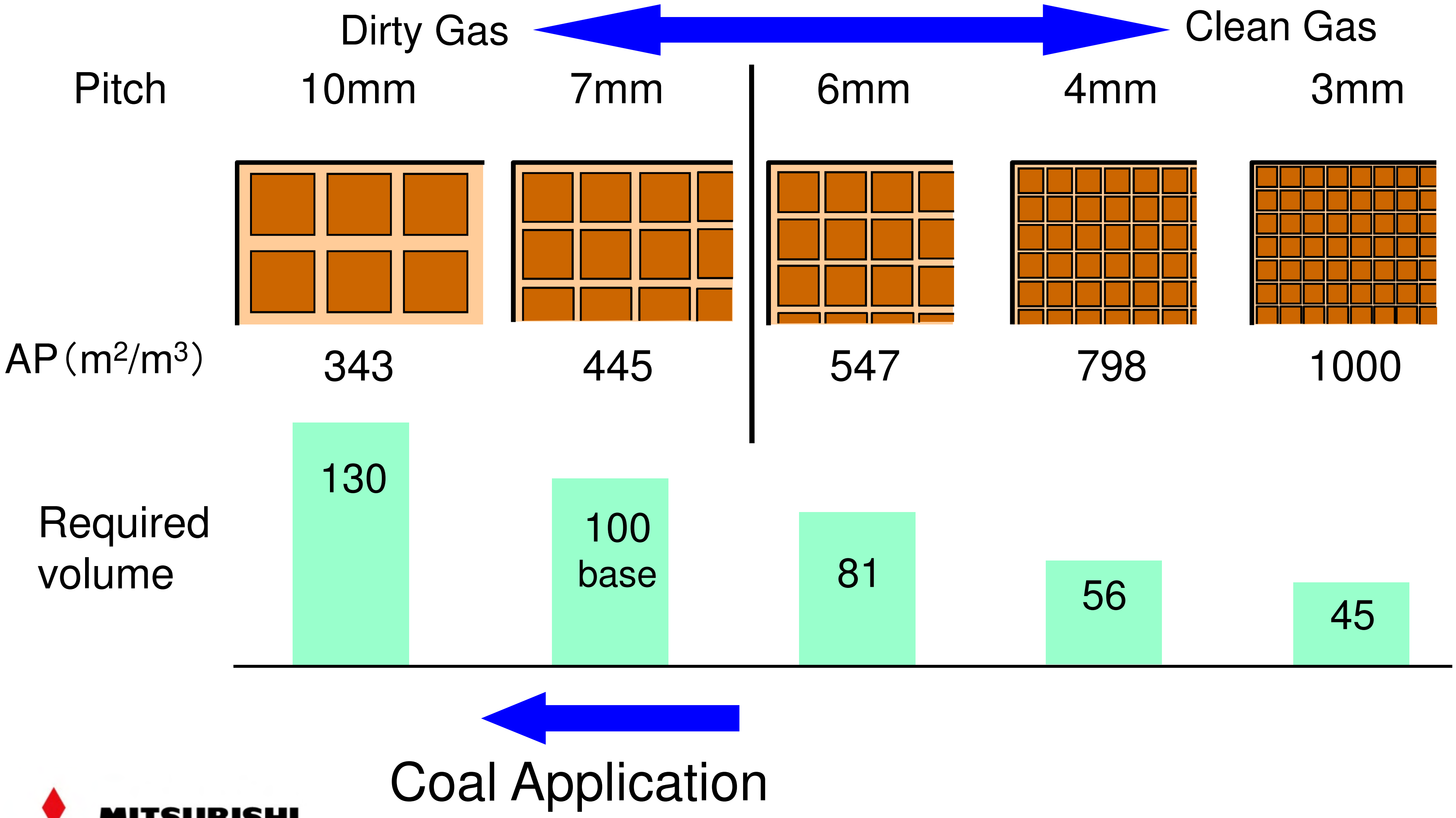
TYPICAL HONEYCOMB CATALYST PITCH SELECTION



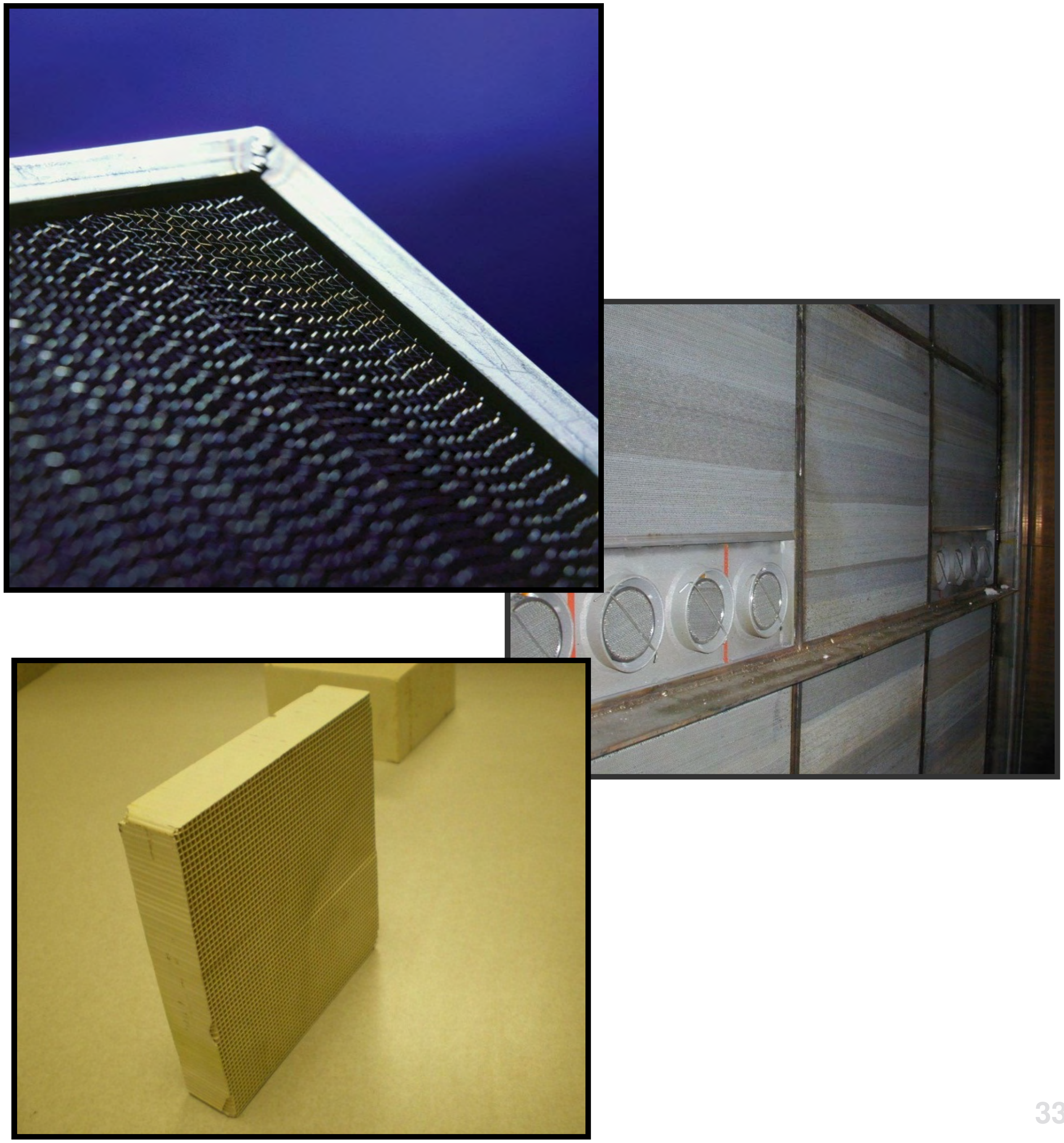
Dirty Gas ⟷ Clean Gas

Pitch	10mm	7mm	6mm	4mm	3mm
AP（m²/m³）	343	445	547	798	1000
Required volume	130	100 base	81	56	45

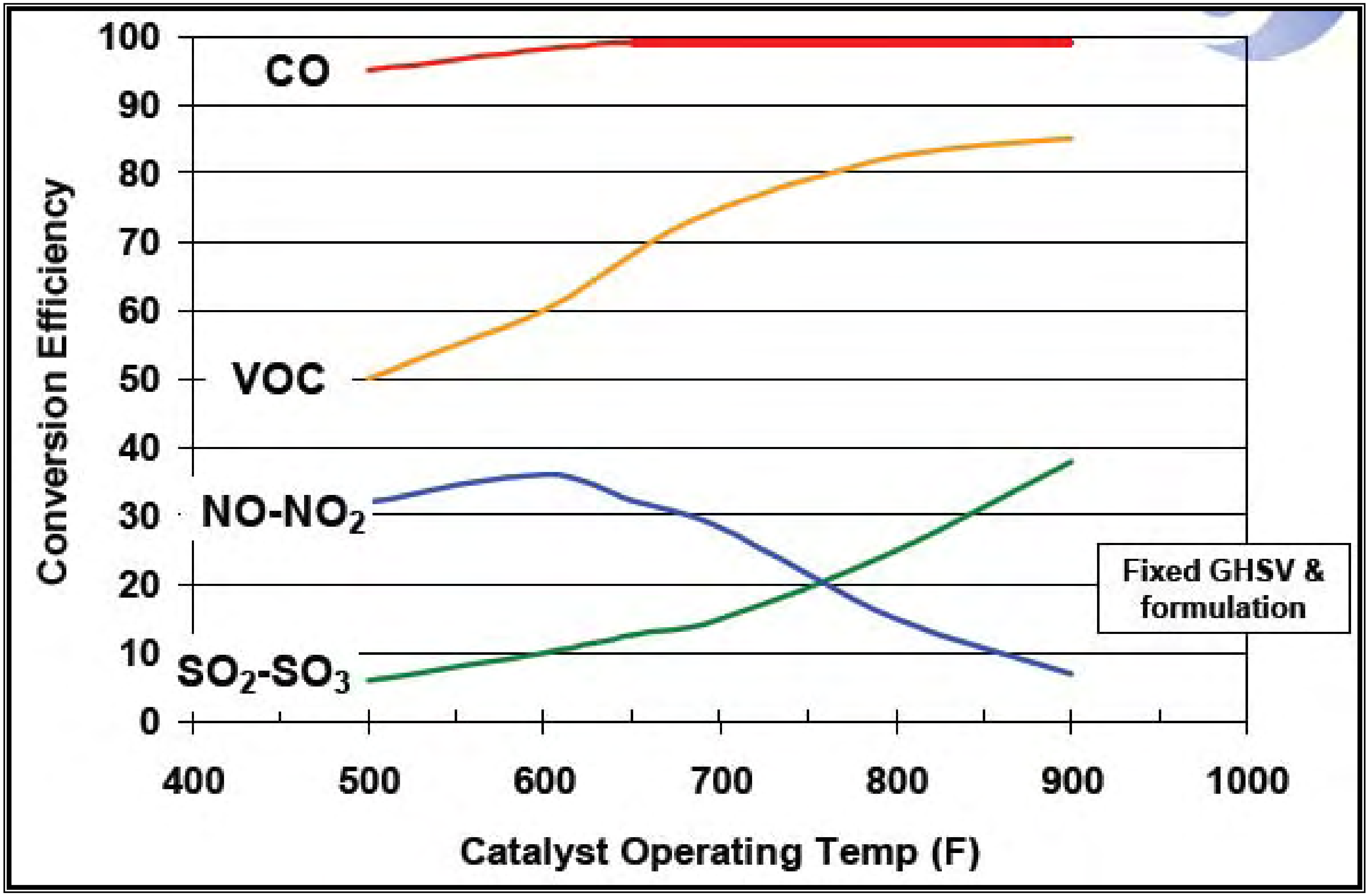
Coal Application

CO & VOC CATALYST

- Platinum or other PGM promotes CO to CO_2 oxidation.
- Brazed joint corrugated metallic foils, stacked corrugated foil or ceramic cells to provide high surface area per cu.ft. of catalyst
- Oxidation occurs on “surface” of catalyst.
- Pressure drop is directly dependent on catalyst depth and compactness



TEMPERATURE VS. CATALYST ACTIVITY - CO



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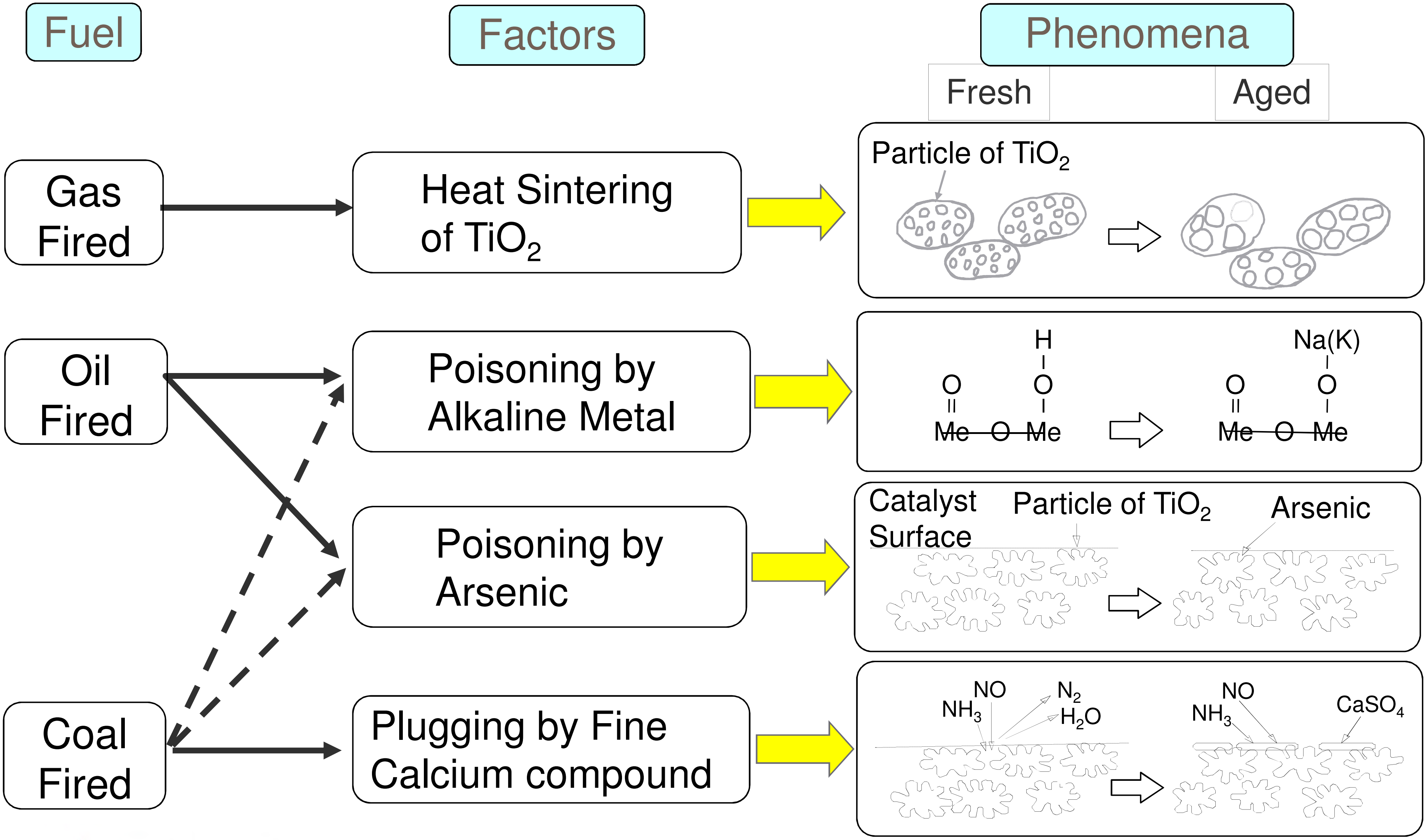
CATALYST POISONING & DEGRADATION MECHANISM

Degradation Source	Mechanism
High Temperature	Decreases available surface area by thermal sintering of ceramic material
Fine particulate	Reduces available surface area by masking surface and preventing diffusion into pre structure
Ammonia-sulfur compounds	Plugs pores and prevents diffusion
Alkaline metals, Na, K	Ion exchange with active sites
Alkaline earth metals, Ca, Mg	Typically in form of sulfates, bond with acid sites reducing the ability of catalyst to absorb NH_3 I.e. formation of $CaSO_4$
Halogen	May react with and volatilize active metal sites
Arsenic	Gaseous arsenic diffuses into catalyst and covers active sites, preventing further reaction
V, Pt, Cr and Family	Deposit onto catalyst, increasing NH_3 to NO and/or SO_2 to SO_3

CATALYST DETERIORATION FACTOR



Fuel

Factors

Phenomena

Fresh

Aged

Gas Fired

Oil Fired

Coal Fired

Heat Sintering of TiO_2

Poisoning by Alkaline Metal

Poisoning by Arsenic

Plugging by Fine Calcium compound

REACTOR MODELING

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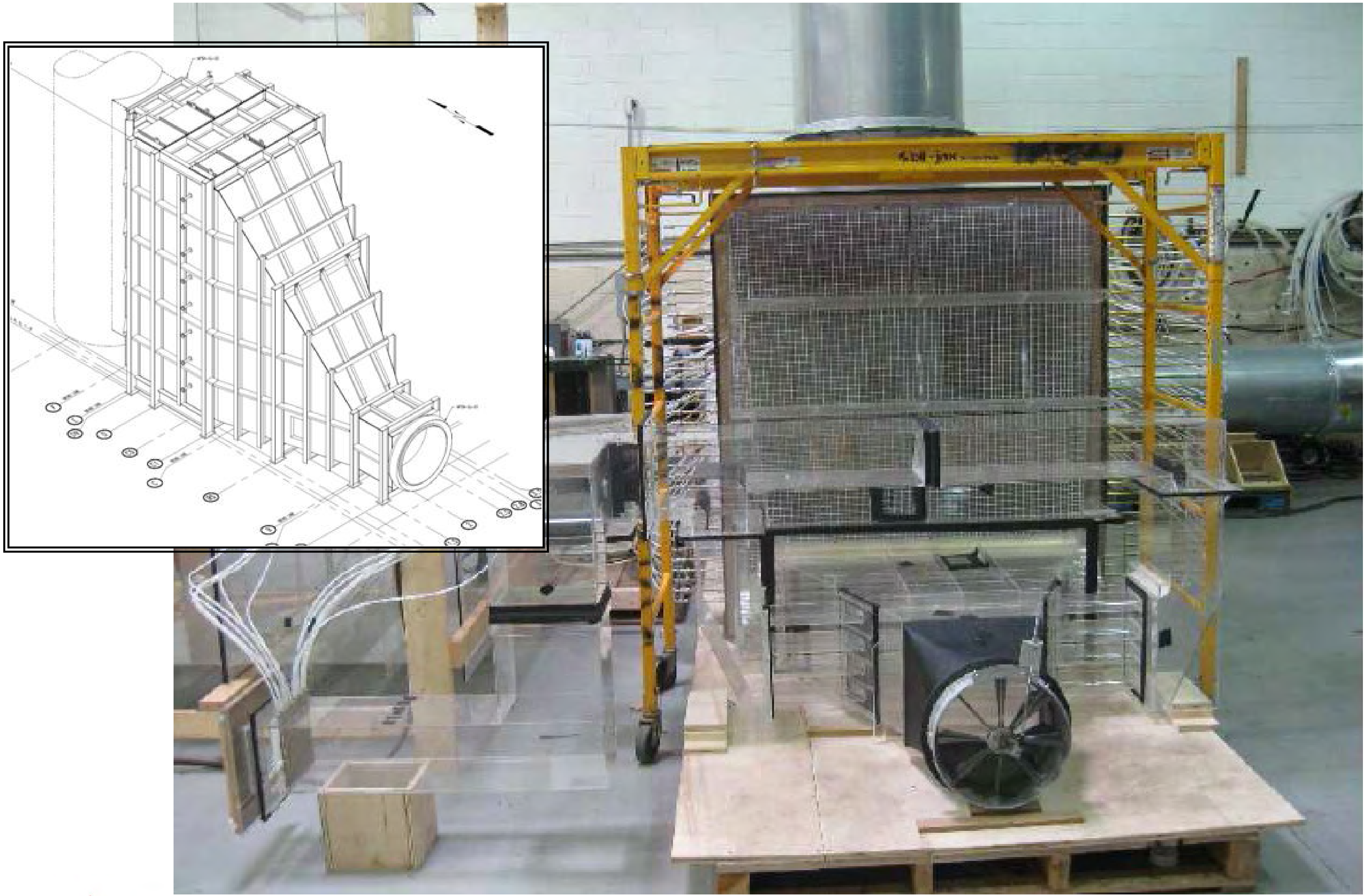
COLD FLOW MODELING

- Cold flow modeling is the core method of determining complex flow fields.
- Scale of 12:1 typically used.
- All internal structures greater than 6” diameter are duplicated
- Highly reliable data achieved based on actual flow conditions
- Used in Concert with CFD modeling

FLUE GAS PATH MANAGEMENT (NH$_3$ MIXING - COLD FLOW MODEL)



Simple Cycle Physical 1/12th Scale Model

HIGH VOLUME TEMPERING AIR SYSTEMS

- Major Design Concern;

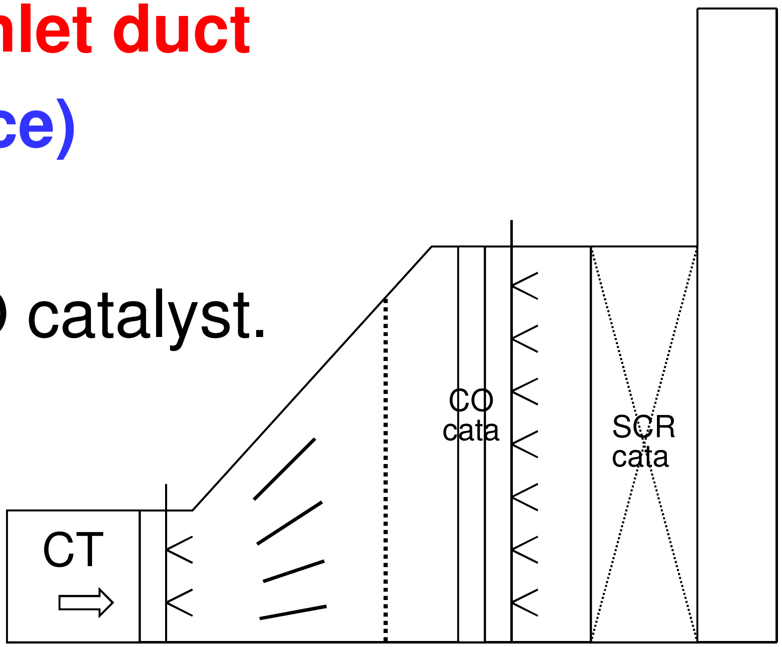
a) Short Distance Available to Mix the Air

b) Conflicting requirement at the inlet duct

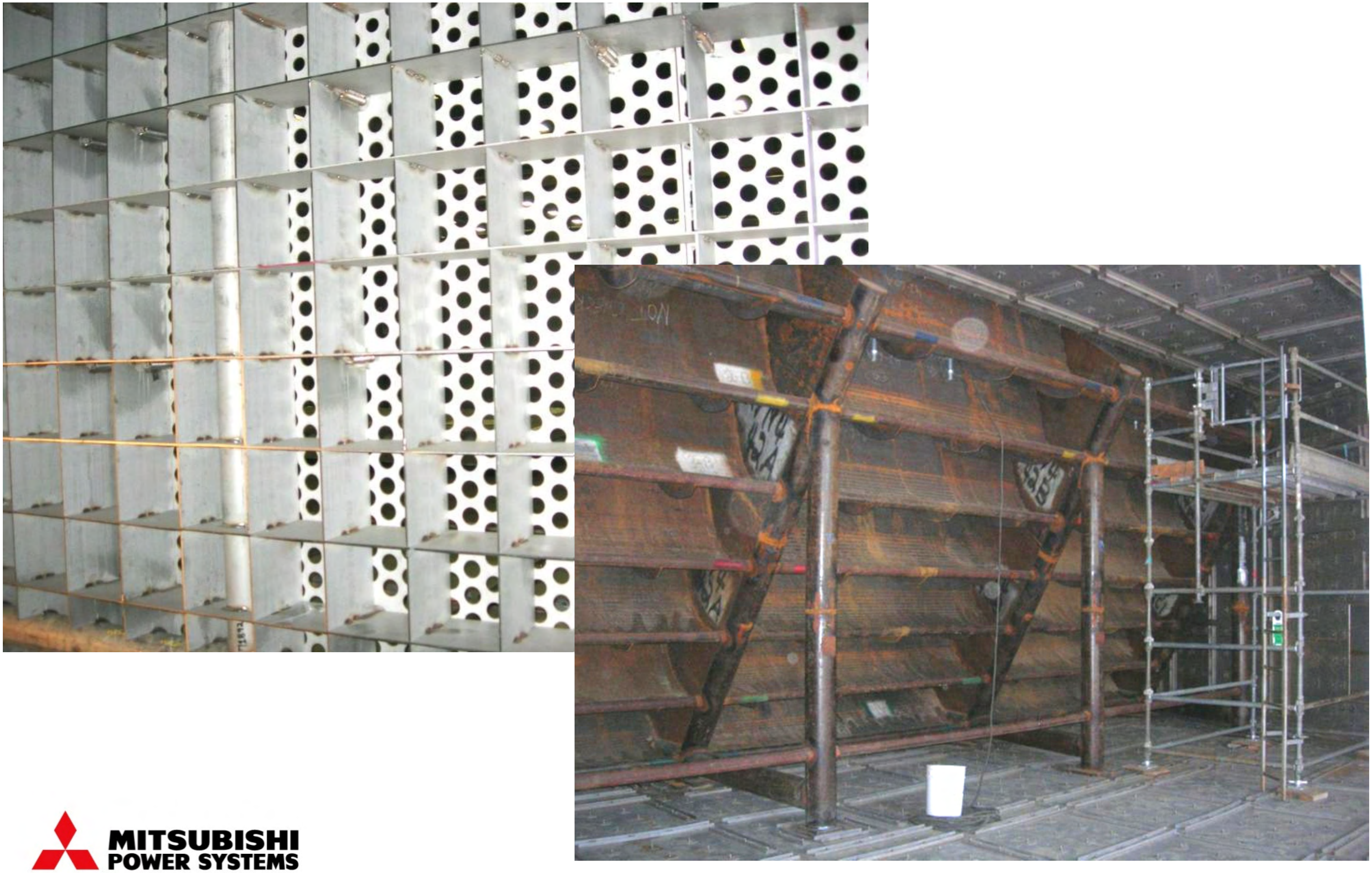
Mix the air into flue gas **(Turbulence)**

v.s.

Uniform gas flow necessary for CO catalyst. **(Straightening)**



PERFORATED PLATE & TURNING VANES



TEMPERING AIR SYSTEM REDUNDANCY & SIZE

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HOT SCR FOR SIMPLE CYCLE GT
NO TEMPERING AIR SYSTEM

SCR SYSTEMS CONSTRUCTABILITY

LOWEST SUPPLIED COST
LOWEST INSTALLED COST

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PLANT A (MODULAR CONSTRUCTION)

PLANT B (PANEL CONSTRUCTION)

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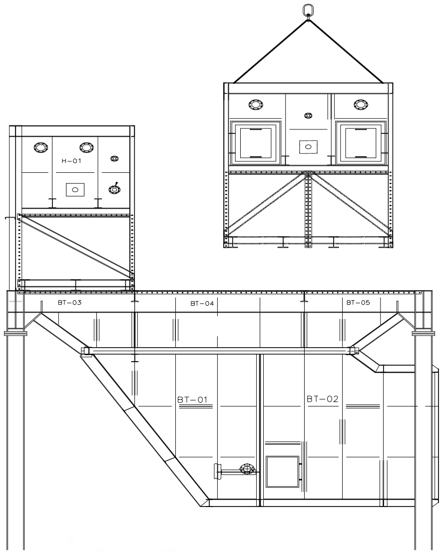
PLANT C (SEMI-MODULAR CONSTRUCTION)

SCR Housing Field Welding (Lineal Feet)

As-Built	Modular
100% (Base)	40%

CONSTRUCTABILITY (MODULARIZATION)

- Modularization (Lower Total Installed Cost):
  - Modularize SCR reactor/ductwork to maximum extent possible in order to minimize field weld and labor cost.
  - Full shop preassembly of components, match marked and alignment holes (helps to minimize field changes and associated cost)
  - Flexibility in Construction



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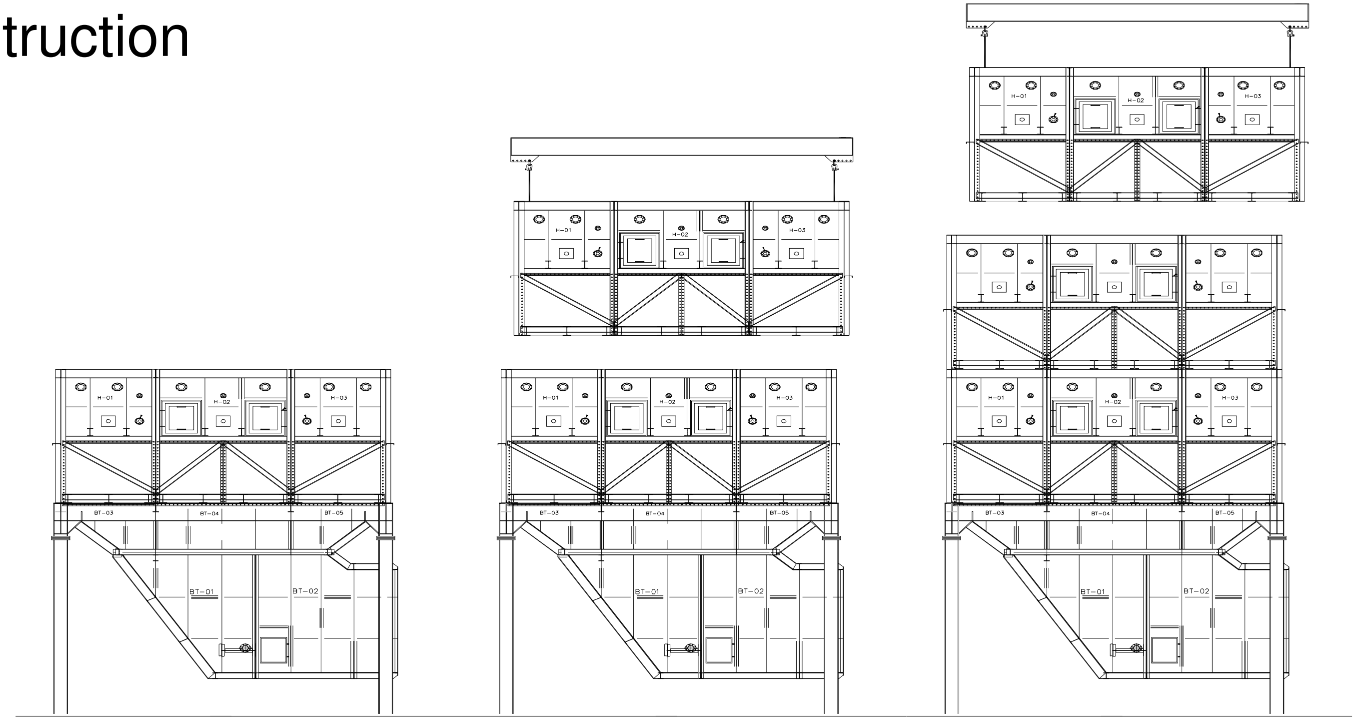

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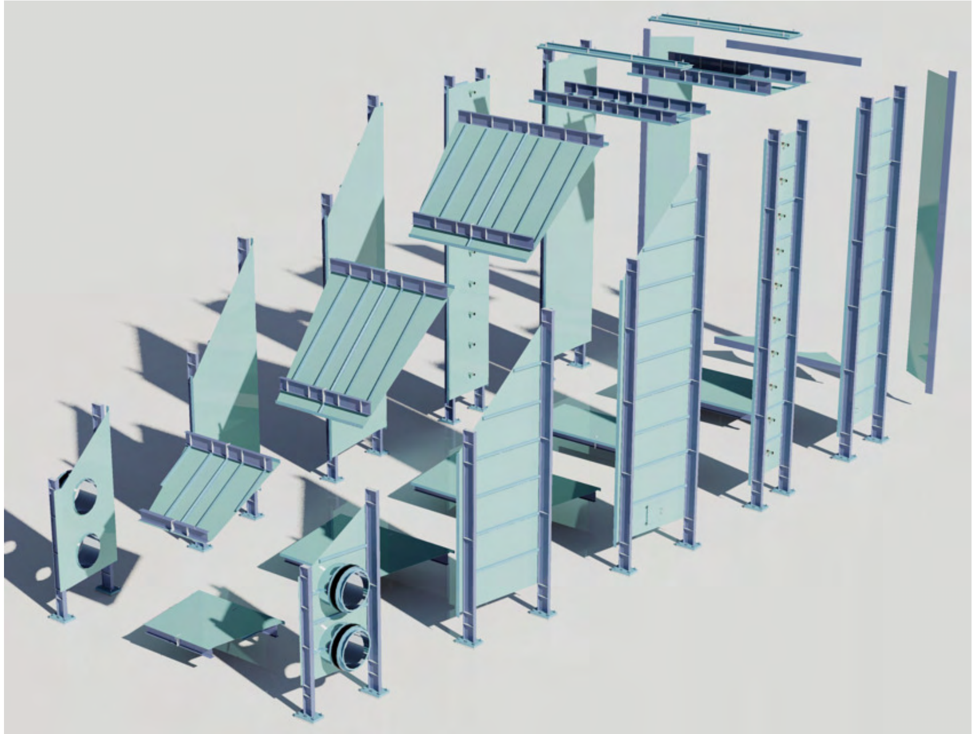
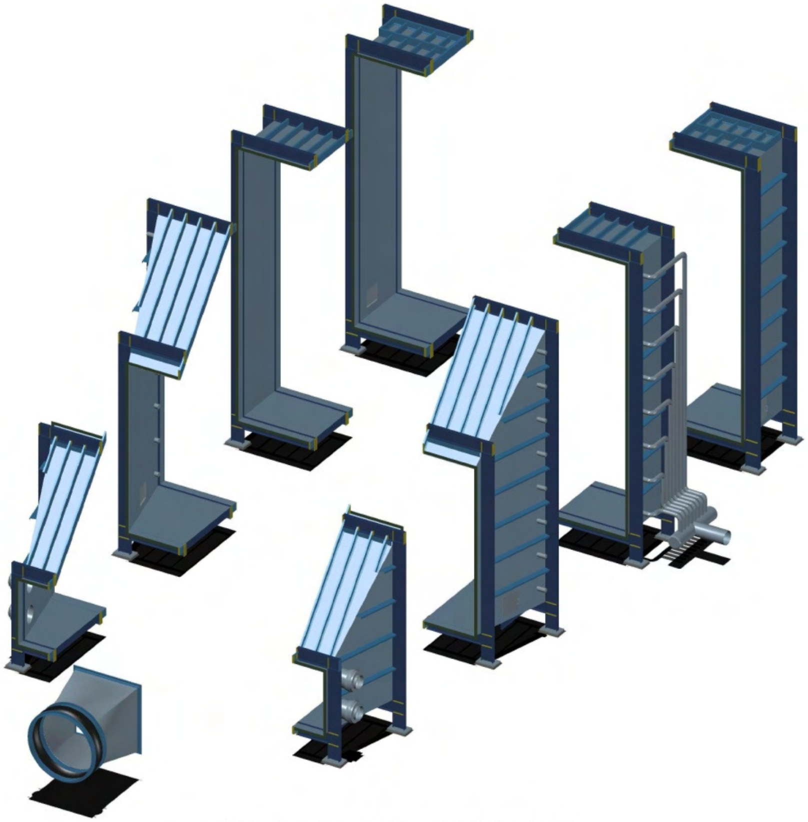
PANEL & MODULAR CONSTRUCTION METHODS





SUBASSEMBLY UNITS

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GT SCR & CO CATALYST LOADING

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AMMONIA SYSTEMS

AQUEOUS, ANHYDROUS, UREA

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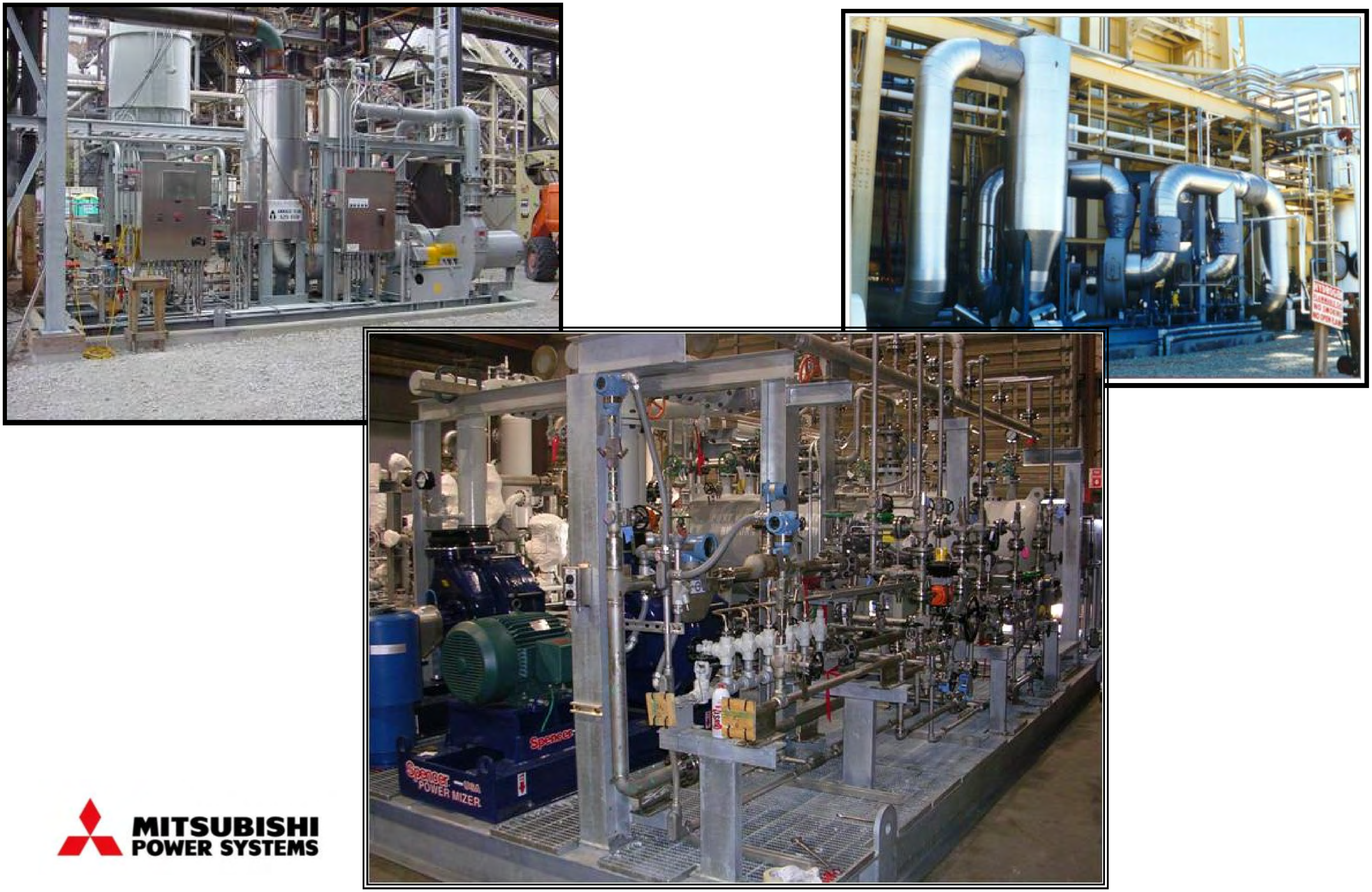
AMMONIA SYSTEM ESTIMATED COST COMPARISON

	Anhydrous	Aqueous (19%)	Urea
Equipment Cost	100%	125%	160%
Reagent Cost	100%	145%	105%
Utility Consumption	100%	650%	400%

- Estimation per 150 kg/hr as Anhydrous Ammonia in USA.
- Equipment cost is for the ammonia vaporization skid only (vaporizer system, dilution air system and flow control unit).
- Utility consumption is based on electricity use.
- Urea system becomes competitive if the unit capacity is small.

Typical Ammonia System

(AFCU Skid)



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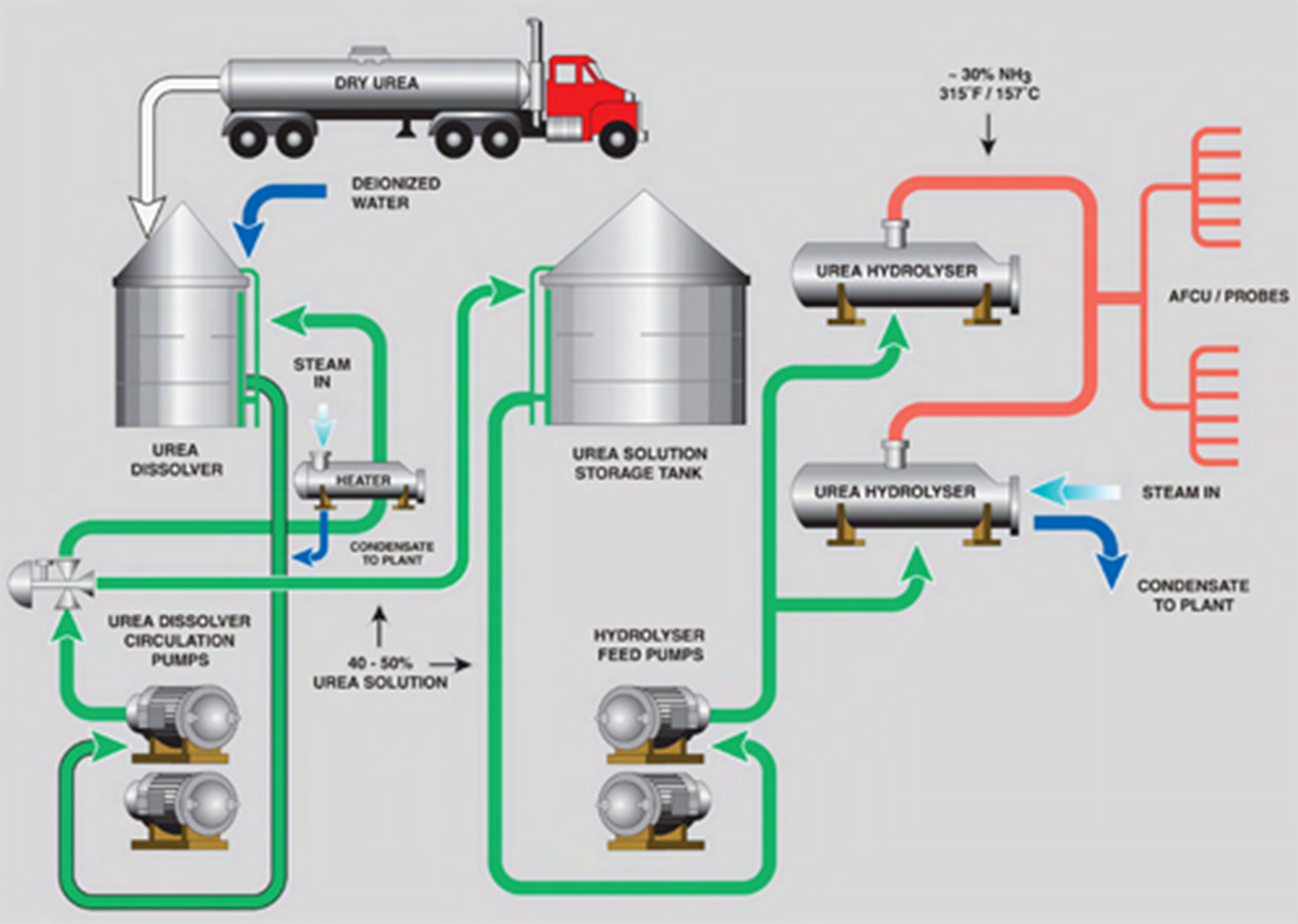
HOW DOES U2A® WORK?



Dissolve Urea
(Urea + Water)

↓

Hydrolyze
Urea Solution

↓

Deliver
Product Gas
(on-demand)

WAHLCO

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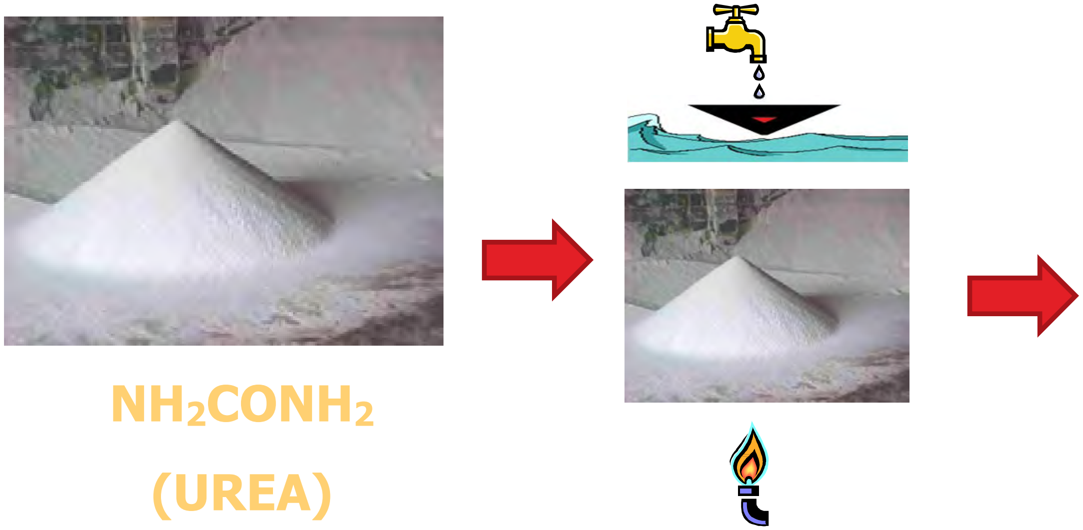
SPECIFIC HYDROLYSIS REACTIONS



NH_2CONH_2

(UREA)

$NH_3 + CO_2$ + Water Vapor

$(x)H_2O + NH_2CONH_2 \rightarrow NH_4COONH_2 + (x-1)\ H_2O$

Ammonium Carbamate Intermediate Consumes One Molecule of Water. Heat and Pressure Required to Force Water to Combine.

$NH_4COONH_2 + (x-1)\ H_2O \rightarrow 2NH_3 + CO_2 + (x-1)\ H_2O$

Ammonium Carbamate Fully Converts to 2 Molecules of Ammonia

WAHLCO U2A® HYDROLYZER

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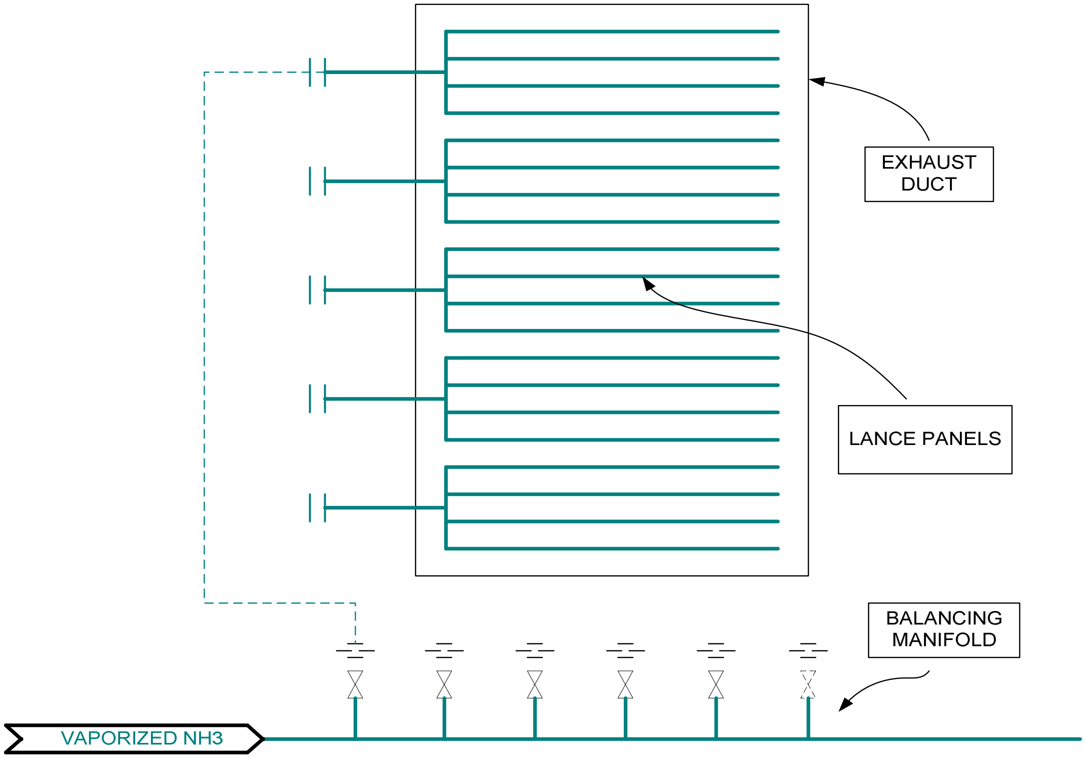
HOT GAS VAPORIZER & AIG

SIMPLE GRID W/BALANCING VALVE MANIFOLD



MPSA PROPOSAL BASIS
GE 7FA.03 CT

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DESIGN CONDITIONS

OPERATING CONDITION		ISO	WINTER	SUMMER	PART LOAD	PART LOAD
CTG Load	%	100	100	100	50	75
Ambient Temperature	degF	59	0	100	59	59
RH	%	60	60	45	60	60
CTG Exhaust:	Per Unit					
Flow Rate	klbs/hr	3,526	3,912	3,307	2,578	2,837
Temp. (normal expected)	degF	1,126	1,071	1,149	1,068	1,200
Temperature (maximum)	degF	1,210	1,210	1,210	1,210	1,210
Argon	wt% wet	0.890	0.900	0.870	0.890	0.890
Nitrogen	wt% wet	74.410	75.080	72.650	74.850	74.340
Oxygen	wt% wet	12.520	12.660	12.120	13.770	12.310
Carbon Dioxide	wt% wet	3.830	3.850	3.780	3.250	3.920
Water	wt% wet	8.360	7.510	10.570	7.240	8.550
NOx (max)	ppmvdc*	9	9	9	9	9
CO (max)	ppmvdc*	7.4	7.4	7.3	8.8	7.1
VOC (max)**	ppmvdc*	1.2	1.2	1.3	1.5	1.2
PM 10 particulates (max)	lbs/hr	8.3	8.3	8.3	8.3	8.3

- * Corrected to 15vol%-dry O_2.
- ** VOC is non-methane, non-ethane, 50% saturated
- NO2 is not greater than 30% of total NOx at the combustion turbine outlet under any operating condition.
- Assumes no metal deposition on the catalyst..

.

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PERFORMANCE GUARANTEE

Item		Guaranteed Value	
Stack Outlet NOx	ppmvdc*	2	1 hour rolling average
Stack Outlet CO	ppmvdc*	2	
Stack Outlet VOC	ppmvdc*	1	
Ammonia Slip	ppmvdc*	5	
PM 10 particulates increase**	lbs/hr	4.7	
Total System Pressure Loss***	in WC	13	
CT Outlet Back Pressure (Static)	in WC	9	
Noise Level****	dBA @3ft	85	
Catalyst Life		The earliest of 25,000 operating hours or 60 months from startup (first gas-in) or 66 months from contracted delivery.	

* Corrected to 15vol%-dry O_2.

** Increase of PM10 across the SCR system is based on 4.14lb/hr of CTG SO_2 emissions.

*** Total system pressure loss is the loss of total pressure between CT outlet transition and stack outlet, excluding stack effect and discharging loss at stack outlet.

**** At 3 feet horizontal from the exhaust system and 5 feet above grade.

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SUMMARY

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SUMMARY

- Catalyst supply record for installations operating successfully at temperatures of 850F or higher is over 70 for Cormetech alone. Johnson Matthey and Haldor Topsoe also have good success and reliability at these continuous temperatures
- Successful system design requires highly defined CFD modeling to assure good temperature mixing
- Important design considerations include adequate tempering air, proper catalyst selection, temperature and velocity distribution, and ammonia injection.
- F Class and larger combustion turbines can be deployed with high temperature SCRs installed at low risk as proven by our successful installations/ designs

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Mitsubishi is the Right Choice.

MITSUBISHI POWER SYSTEMS AMERICAS, INC.

100 Colonial Center Parkway
Lake Mary, FL 32746
(407) 688-6800

Rand Drake (Gen. Manager, SCR Group)

100 Bayview Circle, Suite 6000
Newport Beach, CA. 92660
(949) 856-8400

Bob McGinty (Sr. Manager Bus. Dev.)

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EXHIBIT 4

Simple Cycle
SCR Operating Experience

Cormetech, Inc.

Christopher Bertole, Ph.D.
Elizabeth Mancini Govey

New York Power Authority

Mike Stockstad

Nooter/Eriksen

Martin Nygard

POWER-GEN International, December 6-8, 2005

Overview

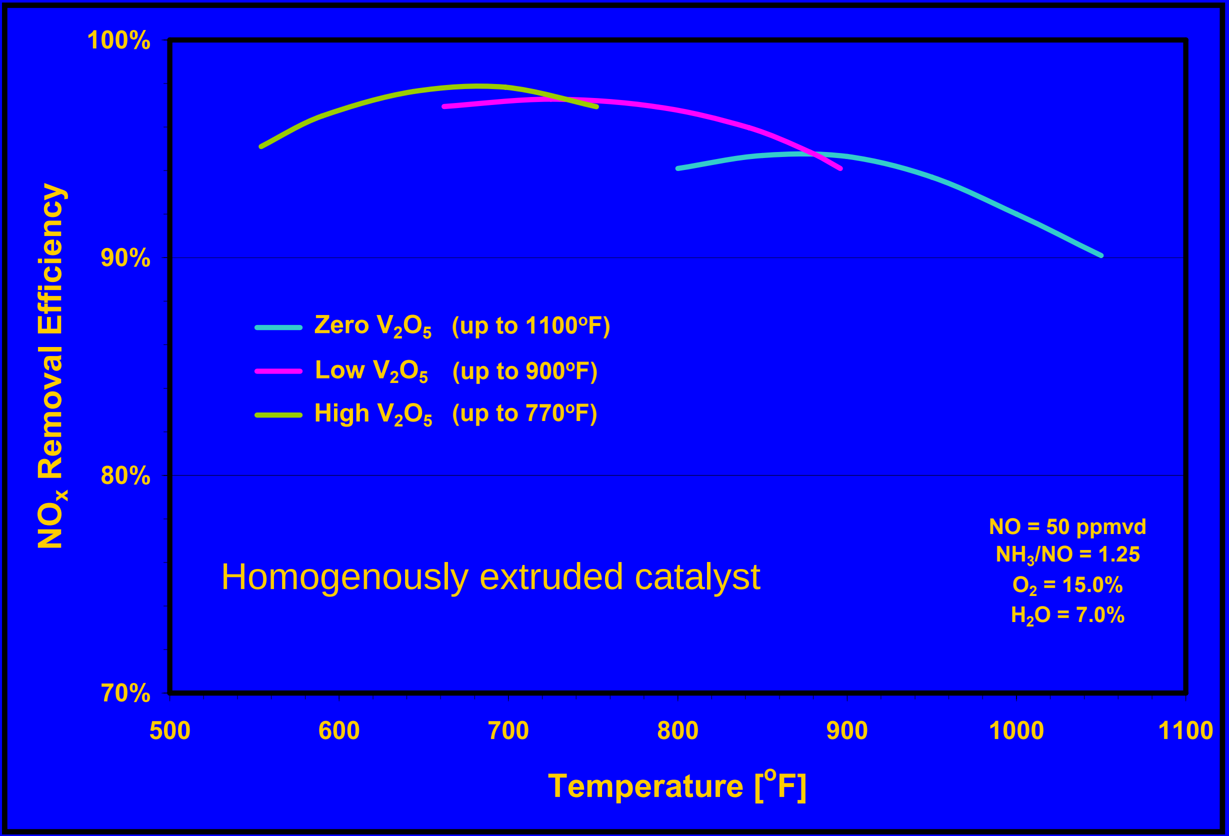
- SCR design considerations and catalyst selection for simple cycle gas turbines
- Field operating experience

Exhaust Gas Characteristics

Unit Type	Power [MW]	Flue Gas Flow [lb/hour]	Exhaust Gas Temp ºF
GE LM6000	45	1,051,200	840
GE LMS100	99	1,642,000	820
GE Frame 7EA	85	2,400,000	997
GE Frame 7FA	172	3,531,800	1113
SGT6-5000F	198	3,967,200	1070
MW-701D	144	3,595,300	991
MW-501D	150	2,810,000	1112

V_2O_5-WO_3/TiO_2 NH_3-SCR Catalysts

Large operating temperature range (350 - 1100°F)



Homogenously extruded catalyst

NO = 50 ppmvd
NH_3/NO = 1.25
O_2 = 15.0%
H_2O = 7.0%

Reaction Network

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

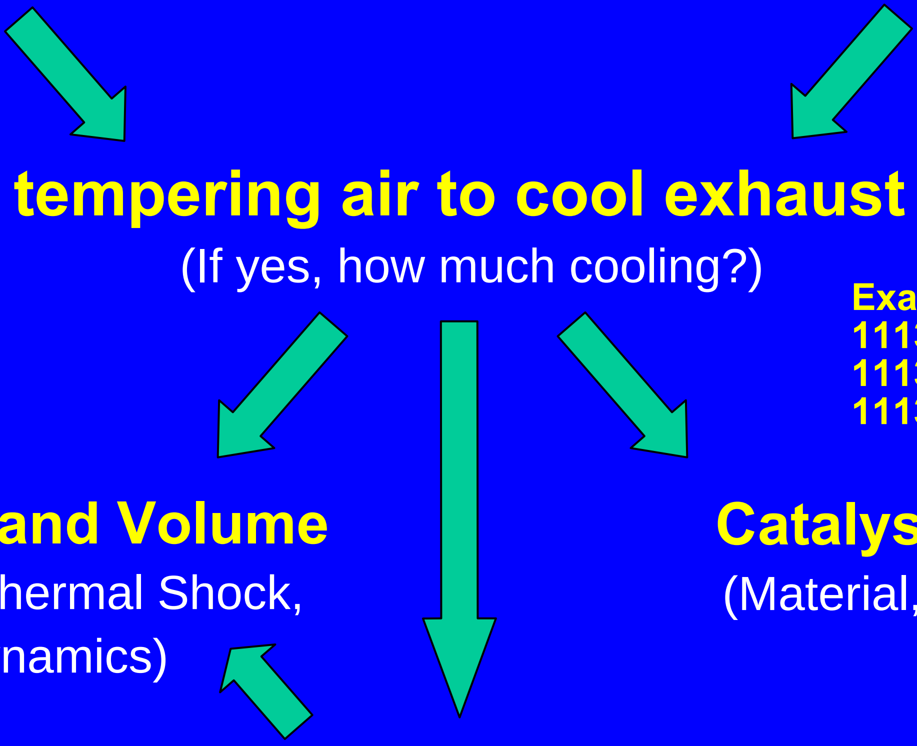
$4\ NH_3 + 3\ O_2 \rightarrow 2\ N_2 + 6\ H_2O$

$4\ NH_3 + 5\ O_2 \rightarrow 4\ NO + 6\ H_2O$

At higher temperature, reduce V:W ratio for

- Stronger NH_3 adsorption
- Lower NH_3 oxidation rate
- Higher DeNOx rate
- Lower sintering rate

SCR Design Considerations



Performance Requirements

(DeNOx, NH_3 slip, DP, Life (capacity factor))

Exhaust Gas

(T, Composition, Flow)

Add tempering air to cool exhaust gas?

(If yes, how much cooling?)

Example: Frame 7FA
1113°F → 1000°F (zero V)
1113°F → 850°F (low V)
1113°F → 780°F (high V)

Catalyst Type and Volume

(NH_3 Oxidation, Thermal Shock, Start-up Dynamics)

Catalyst Modules

(Material, Size, Seals)

System Maldistribution

(Flow, T, AIG design, NH_3/NO_x)

Tempering Air System Design

Nooter/Eriksen experience

- successfully implemented tempering air systems designed through cold flow model testing on 11 LM6000 applications
- performed field testing to validate even temperature and velocity distributions at the catalyst face
- worked with NYPA to evaluate and improve the temperature distribution on LM6000 units

SCR with Tempering Air Cooling

Benefits

- + Use catalyst with higher V:W ratio
  - + Less volume
  - + Lower DP
- + Longer catalyst life guarantees
- + Module design
  - + May be able to use carbon steel; larger modules

Costs

- – Fans required (capital, operating costs; added space)
- – Catalyst can overheat if fan failure occurs

SCR without Tempering Air Cooling

Benefits

- + No fans required (save capital, operating costs; less space)
- + No risk of catalyst overheating

Costs

- – Requires a catalyst with lower V:W ratio
  - – More volume; Higher DP
- – Shorter catalyst life guarantees if >1000°F
  - – Management plan (extend life, reduce total volume)
- – Module design
  - – Chrome-moly steel; Smaller modules

Determining the Optimal Solution

Economic Analysis

- Fans (size: capital, operating costs, failure risk), catalyst type and volume, DP, life (capacity factor), modules, catalyst management plan
- Space requirements, if any

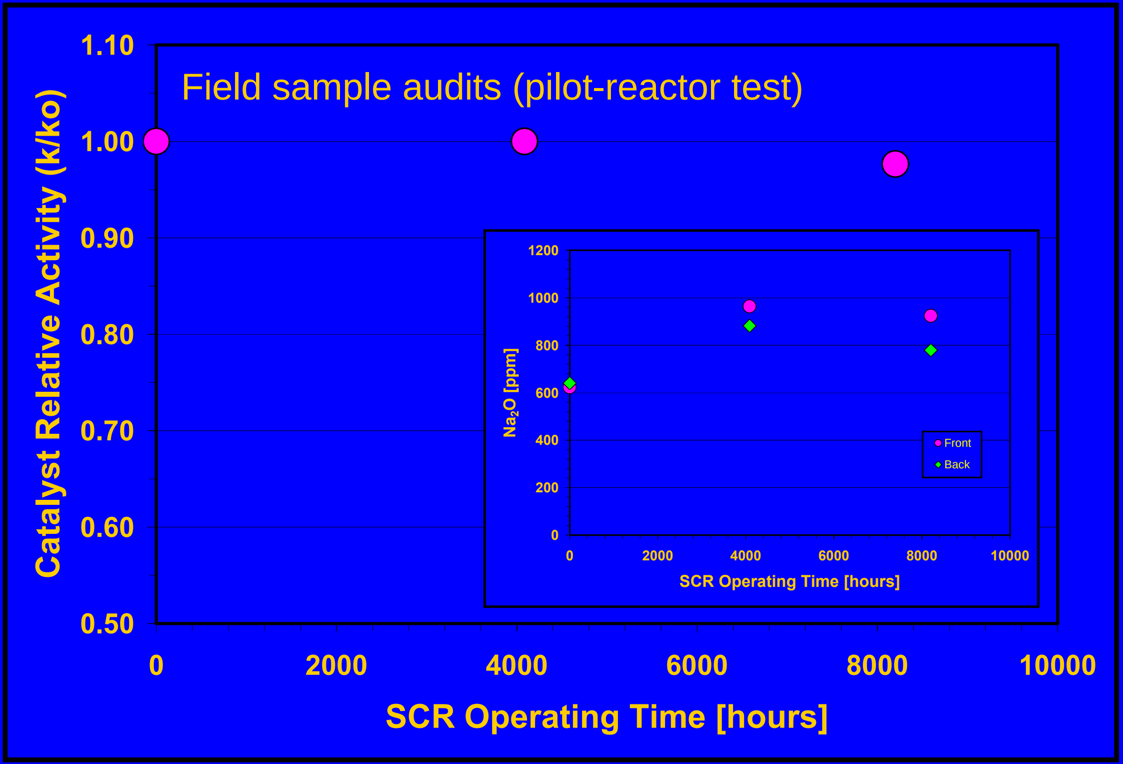
Bottom Line

- SCRs can be designed and successfully operated for simple cycle gas turbines using homogeneously extruded V-W-Ti catalysts, with or without tempering air cooling
- *Approach is very case specific*

Long Island Simple Cycle LM6000

With tempering air cooling for SCR design (720ºF)

Installed (2002): Cormetech high V_2O_5 catalyst



Guarantees:

2.5-ppmvdc Outlet NO_X

91.5% $DeNO_X$

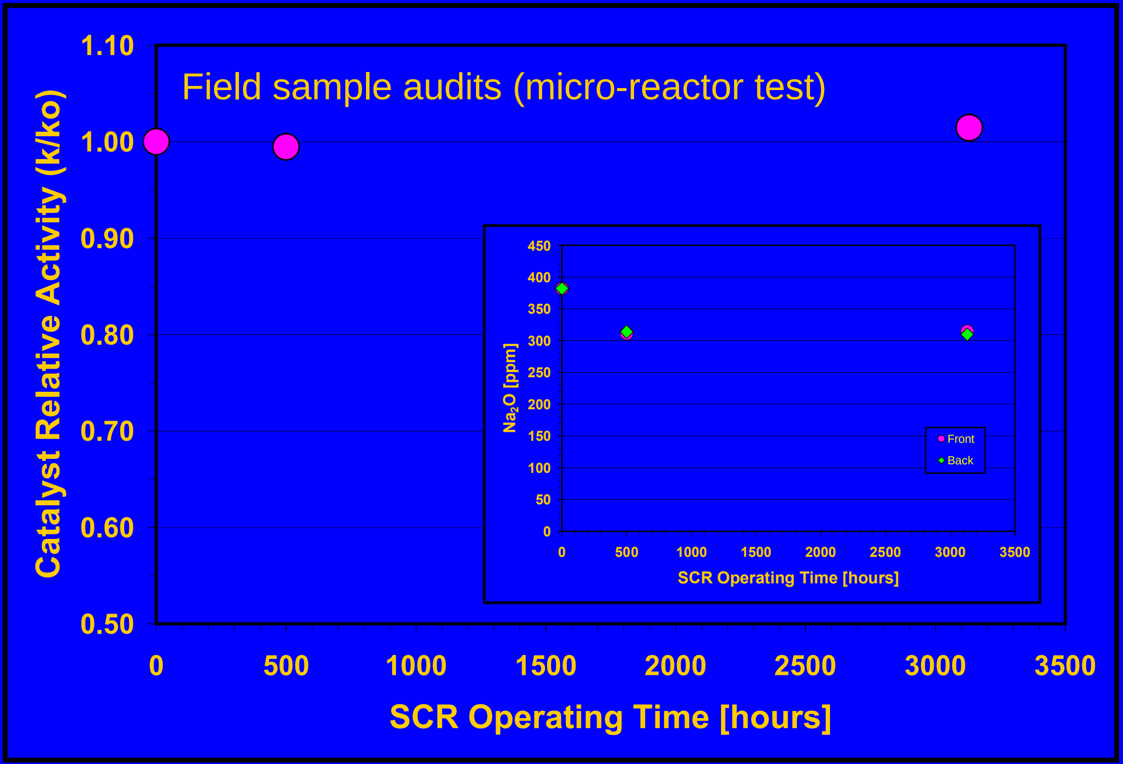
9-ppmvdc NH_3 slip

3-years life

NYC Simple Cycle LM6000

No tempering air cooling for SCR design (840ºF)

Installed (2004): Cormetech low V_2O_5 catalyst



Guarantees:

2.5-ppmvdc Outlet NO_X

90% $DeNO_X$

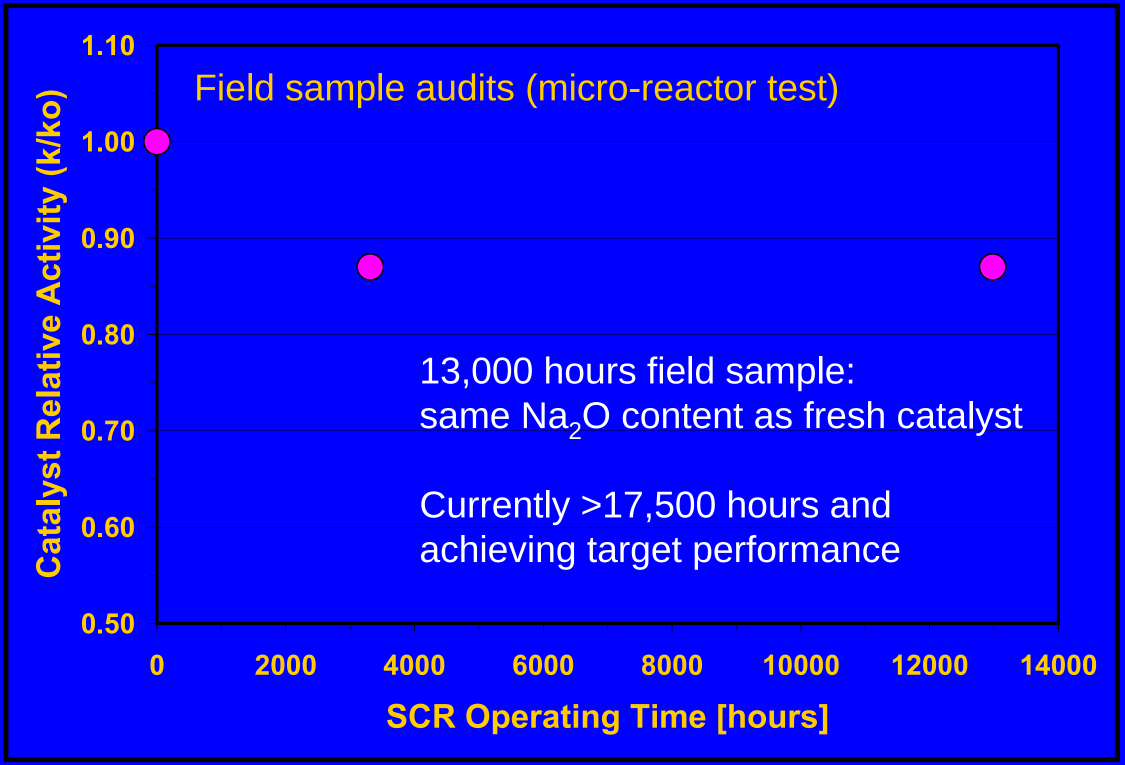
7-ppmvdc NH_3 slip

18,000-hours or 5-years

California Simple Cycle LM6000

No tempering air cooling for SCR design (874°F)

Installed (1996): Cormetech zero V_2O_5 catalyst



13,000 hours field sample:
same Na_2O content as fresh catalyst

Currently >17,500 hours and
achieving target performance

Guarantees:

2.5-ppmvdc Outlet NO_x

90% $DeNO_x$

7-ppmvdc NH_3 slip

18,000-hours life

California Simple Cycle Frame 7EA

No tempering air cooling for SCR design (1000°F)

Installed (2003): Cormetech zero V_2O_5 catalyst

Guarantees:	Current status:
4.2-ppmvdc Outlet NO_x	315 operating hours
90.1% $DeNO_x$	46 starts and stops
10-ppmvdc NH_3 slip	Outlet NO_x = 3.5 ppmvdc
8,400-hours life	NH_3 slip = 3.1 ppmvdc

Simple Cycle Field Experience

Unit Type	# Operating Sites	Tempering Air	Catalyst Type	Op Temp ºF	Op Hours
LM6000	12	no / available	low vanadia	760-840	up to 3,100
LM6000	9	yes	high vanadia	720-750	up to 8,200
LM6000	1	none	zero vanadia	864	>17,500
LM5000	1	no / available	low vanadia	805	>700
LMS100	1	no / available	low vanadia	846	construction
7EA	1	no / available	zero vanadia	1000	315
MW701D	1	none	zero vanadia	991	>4,000
MW501D	1	none	zero vanadia	1112	>4,000
diesel engine	4	none	zero vanadia	750-1020	>100
boiler	2	none	zero vanadia	910-925	up to 8,000

Summary

Extruded honeycomb V-W-Ti SCR catalyst is a proven solution for simple cycle gas turbine applications

- Can design with or without tempering air for exhaust cooling
- Extensive, successful field experience

Contact Information

Cormetech, Inc.

Christopher Bertole, Ph.D.
Lead Catalyst Development Engineer
919-620-3524
bertolecj@cormetech.com

Elizabeth Mancini Govey
Manager, Sales and Engineering
919-595-8715
goveyem@cormetech.com

Booth #5448

New York Power Authority

Mike Stockstad
Charles Poletti Power Plant
718-267-5649
michael.stockstad@nypa.gov

Nooter/Eriksen

Martin Nygard
718-267-5649
mnygard@ne.com

EXHIBIT 5

Hitachi America, Ltd.
Power and Industrial

50 Prospect Avenue, Tarrytown, NY 10591
Tel;(914) 524 6600 Fax;(914) 332-5388
www.hitachi.com/power

LATEST NOX REMOVAL TECHNOLOGY FOR SIMPLE CYCLE POWER PLANTS

By

Isato Morita
Manager, Research and Development Section
Environment Control System Design Department
Backcock-Hitachi K.K.
Akitsu, Japan

Yasuyoshi Kato
Chief Researcher, Environment Research Department
Kure Research Laboratory
Backcock-Hitachi K.K.
Akitsu, Japan

Koichi Kiriyama
Sales Engineer
Hitachi America, Ltd.
Tarrytown, NY

Howard N. Franklin (Presenter)
Technical Manager, SCR
Hitachi America, Ltd.
Tarrytown, NY

Presented To

Power- Gen International; December 10- 12, 2002

Orange County Convention Center – Orlando, FL, USA

ABSTRACT

Hitachi has researched, developed and supplied various flue gas NOx removal technologies for thermal power plants throughout the world, greatly contributing to a cleaner environment. Anticipating the increased used of simple cycle combustion turbines to meet peak power demands the technology was broadened in the 1984 to include high temperature SCR DeNOx catalyst for these applications. After a brief demonstration, three (3) actual operating projects were developed and operated for approximate 5,000 hours at SCR operating temperatures ranging to 1,024 ^{0}F bulk flue gas temperature in the early 1990s. Catalyst substrate, configuration, formulation and ammonia oxidation rates are discussed and characterized. Comparisons with the low temperature catalyst and with material being used for this service today are made demonstrating the superiority of this new advanced high temperature catalyst.

INTRODUCTION

Today, with the competitive electric market and the requirements for a cleaner environment, generators are finding it attractive at times to build to meet seasonal demand or at least start with electric generating peaking simple cycle gas turbines. These units present a unique challenge to the environmental equipment suppliers.

The operating temperatures for the simple cycle NOx reduction system are higher than normally encountered with combined cycle power plants. This puts a severe burden upon the SCR catalyst integrity compared to the medium temperature SCR catalyst. High temperature catalyst is subjected to potentially rapid thermal degradation. Already high temperature SCR catalyst is reported as failing prematurely on both the east and west coast, the authors being aware of three plants total. The high operating temperatures complicate matters further in that the NOx reduction ammonia reagent is oxidized to create additional NOx, requiring both more catalyst and a higher ammonia reagent injection rate, again impacting the NOx. This NOx creation is impacted or catalyzed by the materials within the flue gas path. Thus the materials selected for the inside flue liner, the catalyst support structure, the catalyst modules and even the catalyst itself become important.

Included is actual operating experience for the advanced SCR catalyst discussed, both for testing in the high temperature zones of combine cycle plants and that of actual NOx reduction for simple cycle operation.

ARRANGEMENT

For simple cycle applications, the catalyst treats NOx in the exhaust gas that comes directly from gas turbine. As illustrated in Figure 1, the catalyst is installed in the reactor duct between gas turbine and stack. The gas temperature range where the catalyst is installed is around 900 to 1,100 degree F. For some units the original flue gas may be diluted with ambient air for temperature reduction or optimization to reduce the overall catalyst cost. These cases are excluded from this thesis as when a lower SCR operating temperature is used this allows lower temperature catalyst formulations. In cases where the regulations require CO reduction, a CO catalyst is normally installed upstream of the SCR catalyst and ammonia injection grid. This arrangement is used, as the CO catalyst is an oxidizing catalyst that is kept out of the inlet and outlet streams containing ammonia. This positioning prevents making more NOx by oxidation of the ammonia by the CO catalyst. In addition to the above, the flow leaves the turbine with a swirling motion that requires baffle plates and guide vanes installation upstream of SCR catalyst to assist in obtaining an even inlet flow distribution.

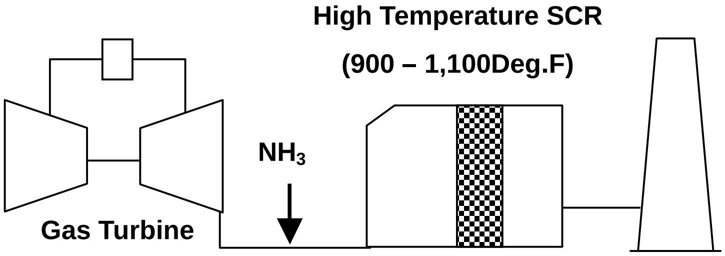


Figure 1 – Simple Cycle Schematic

CHEMICAL REACTIONS

In the high temperature gas flue, there are two types of chemical reactions as shown below: a reduction reaction, reaction (1), and two possible oxidation reactions, reactions (2) and (3). The reduction reaction reduces the NOx, which is required for emission regulations and the oxidation reactions oxidize the ammonia that is injected as the reagent for NOx reduction. Gas temperature, oxygen concentration, the material of casing and structure in the flue and the catalyst materials influence the oxidation reactions. In the high temperature case, the oxidation reactions have to be considered carefully to design the catalyst. From our test results and experience, the ammonia oxidation reactions occur in the flue gas and on the catalyst surface at higher temperatures. This causes a shortage of ammonia reagent to reduce the NOx and increases the amount of NOx (that which comes from ammonia) thereby increasing the required catalyst volume and the ammonia injection rate. Based on our data, the higher gas temperature is, the more ammonia oxidation takes place.

DeNOx Reduction Reaction: $4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$ **(1)**

NH_3 Oxidation Reactions: $4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$ **(2)**

$4NH_3 + 3O_2 \longrightarrow 2N_2 + 6H_2O$ **(3)**

The oxidation reactions have different impacts upon the SCR design. When the ammonia oxidation proceeds to form NOx the catalyst design has to be adjusted to reduce this additional NOx and the injected ammonia has to be increased to add the necessary reagent. More ammonia reagent adds more NOx and the spiral to a larger system begins. The other oxidation reaction causes reagent loses but does not create NOx. Thus only the ammonia injection system is affected. Unfortunately, the authors cannot offer any guidance to determine which or in what combination, the reactions might occur.

TEMPERATURE CHARACTERISTICS

The advanced catalyst DeNOx efficiency varies with gas temperature and catalyst formulation. Figure 2 shows a comparison of efficiency based on gas temperature for both mid and the high temperature SCR catalyst. It is found that the advanced high temperature catalyst can perform at the high efficiencies of mid temperature range catalyst. This means that the advanced catalyst can use minimal cross-sectional flow area to perform the required duty. This advanced high temperature catalyst can cover the entire range of 572 degrees to 1,112^0 F with the peak performance at 842^0. Due to the increased cost of high temperature catalyst, however, it is normally applied over 900^0 F to perform NOx reduction. The higher the gas temperature, the more the catalyst supplier has to consider the NH_3 oxidation and the catalyst's performance period to select most efficient materials and formulation. The advanced high temperature catalyst is thus limited to bulk temperatures of 1,050^0 F with local temperatures not to exceed 1,100^0 to avoid excessive ammonia oxidation. The middle temperature catalyst shown below is considered to apply for combined cycle application. This catalyst can cover the performance in the lower temperature zone, from 900^0 F down to about 570^0 considering lower loads and sliding pressure operation.

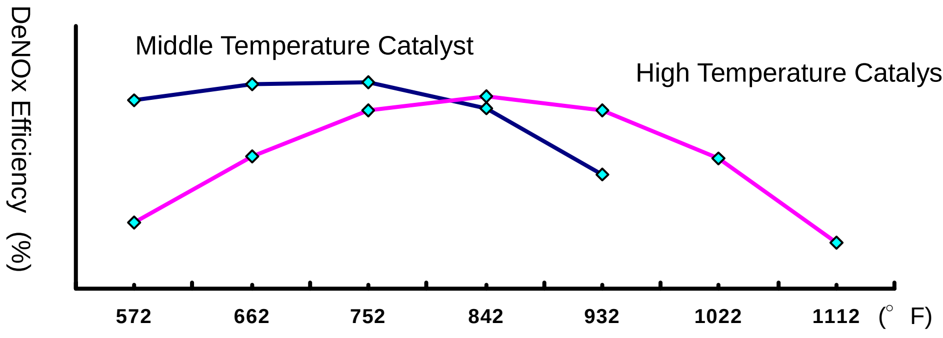


Figure 2 – Efficiency (Activity) with Temperature

OPERATIONAL RESULTS

Table 1 details actual operating flue gas conditions for the advanced high temperature catalyst. Plants A and B are combined cycle projects. Sample catalyst specimens were placed upstream of the HRSG in the hot gas stream directly from the gas turbine for future catalyst activity and durability analysis. As shown here, the sample catalyst in plant A was installed in 1981 about 20 years ago in anticipation of a more immediate demand for high temperature catalyst. Plant C is major Japanese utility demonstration short-lived pilot plant. Subsequently, two simple cycle plants were constructed that included high temperature DeNOx removal systems to treat gas turbine flue gas for two simple cycle projects, which are plants D and E that include the advanced high temperature catalyst for these simple cycle applications.

As shown in the Picture 1, the NOx removal system is located between the flue gas silencer and stack and designed with a horizontal flow reactor. The advanced catalyst performed well with gas temperatures, well over 900^0 F, in each plant, as shown in Table 1,

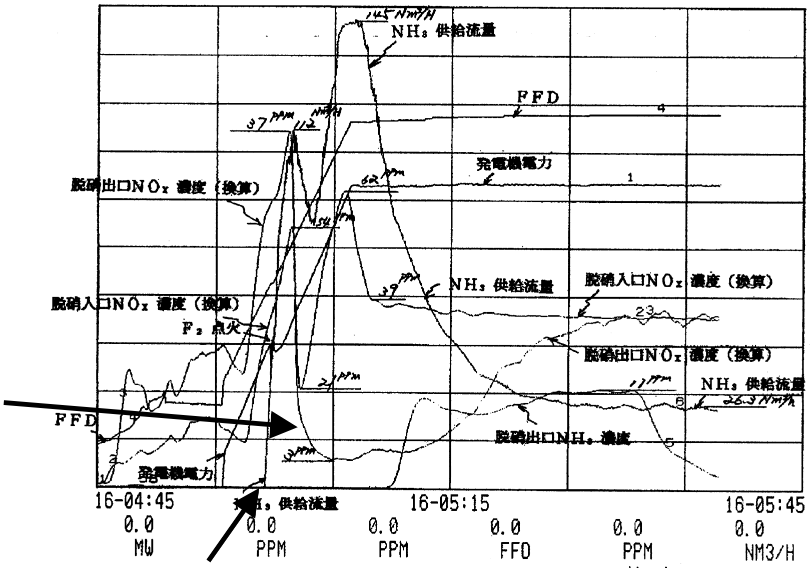
	Description	A plant	B plant	C plant	D plant	E plant
Gas Turbine	GT Type	F9B	F9E	-	F6B	F9E
	Output (MW)	141(Combined)	143(Combined)	-	41.7	127
	Fuel	NO.2 Oil	LNG	LNG	Town Gas	LNG
	Number of Units (Units)	1	1	1	2	1
SCR	Flue Gas Flow Rate (m3N/ h)	977,000	1,012,000	603,000	415,880	1,201,500
Specification	Flue Gas Temperature (Deg.F)	1022	990	1067	993	1024
	Inlet Nox (ppm)	-	-	209 (5%O2)	50 (16%O2)	50 (16%O2)
	Outlet Nox (ppm)	-	-	<40 (5%O2)	<20 (16%O2)	<20 (16%O2)
	Outlet NH3 (ppm)	-	-	<10 (15%O2)	<20 (16%O2)	<20 (16%O2)
	Nox Removal Efficiency (%)	-	-	>80.9	>60	>60
	Date of Competion	1981	1987	1984	1992/ 1993	1993

Table 1

Picture 1 (E plant)

Figure 3 below is a sample commissioning result to show the dynamic characteristics of the advanced catalyst during start up prior and after ammonia injection. During start up, initial ammonia injection began at a gas temperature 572^0 F. After ammonia injection, the outlet NOx begins to decrease smoothly without a significant time lag and achieved the designated NOx outlet conditions within 3 minutes.

The outlet NOx concentration changed rapidly following the introduction of ammonia. The advanced catalyst was found able to withstand the rapid thermal transients of simple cycle service and also that it has a sufficiently rapid response to make it suitable to follow the load changes.



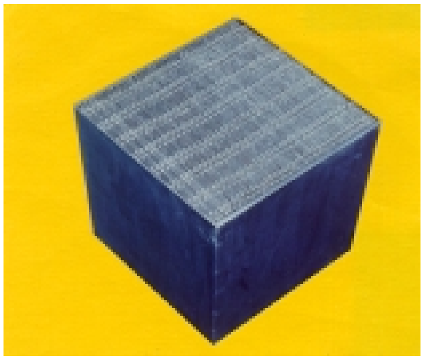
Outlet NOx decreased within approx. 3 min. after NH3 injection.

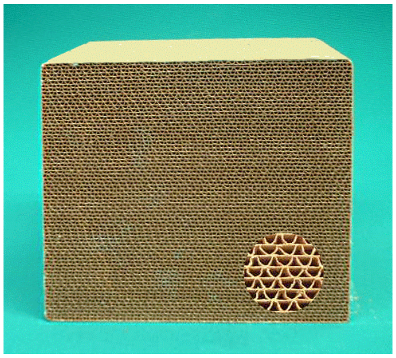
Ammonia injection starts

Figure 3 – Simple Cycle Start-Up Chart

ADVANCEMENTS FOR HIGH TEMPERATURE

Picture 2 shows the unit of mid temperature plate type catalyst. A certain number of catalyst plates are integrated and assembled in the unit box. The ingredients of the catalyst are based on TiO_2 with a substrate that is stainless steal meshed plate. The size of this unit is approximately 465 mm wide, 465 mm high and 500 mm deep where the width and depth dimensions can be adjusted to fit the cross section length of reactor and to perform NOx reduction requirement with low pressure





Picture 2 – Catalyst Unit **Picture 3 – Advanced Catalyst**

drop. This catalyst is typically used for combined cycle and low gas temperature simple cycle applications.

Picture 3 shows the new advanced catalyst for high temperature simple cycle applications. The catalyst base is not stainless steel. In addition, rapid dispatching is critical for simple cycle peaking service: the advanced catalyst can withstand very rapid temperature changes in highly cyclic operation.

To meet such requirements, the newly developed advanced catalyst has a corrugated shape. This shape packs a large surface into a relatively small volume. The short length minimizes the catalyst's thermal resistance and thermal expansion. Also a ceramic material is used as a substrate for the catalyst. This, in the high temperature flue gas zone, minimizes the ammonia oxidation rate. The NH_3 oxidation activity of the advanced high temperature catalyst developed is considerably less than former high temperature catalysts.

The key for performance is the material used for the ceramic substrate. Titanium oxide and vanadium is the typical formulation. However vanadium contributes to ammonia oxidation. Tungsten was considered instead of vanadium but the formulation required a secondary additive to minimize ammonia oxidation. Figure 4 below shows the conceptual formulation of the advanced catalyst. This concept and the corrugated configuration achieved our requirements to get high specific surface area, to reduce the volume and achieve a short depth length, with low ammonia oxidation.

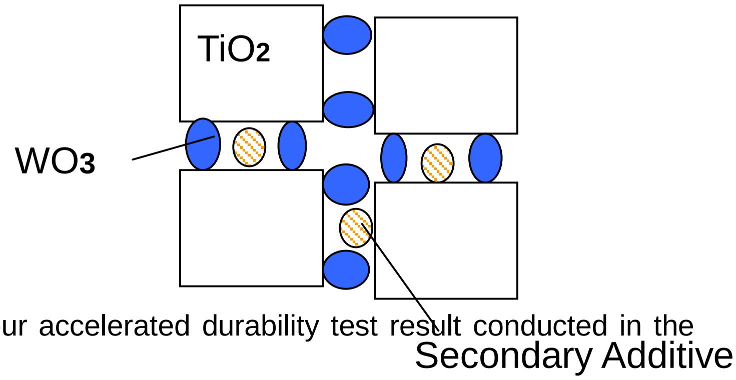


Figure 4 – Catalyst Structure

Figure 5 illustrates the results from a 100 hour accelerated durability test result conducted in the laboratory. The results indicate that the advanced high temperature catalyst formulation can perform longer than zeolite based high temperature catalyst. The accelerated zeolite deterioration was caused by the water concentration in exhaust gas that impacted the crystalline structure. Moisture in the flue gas would be the case for all fuel applications, especially when firing natural gas.

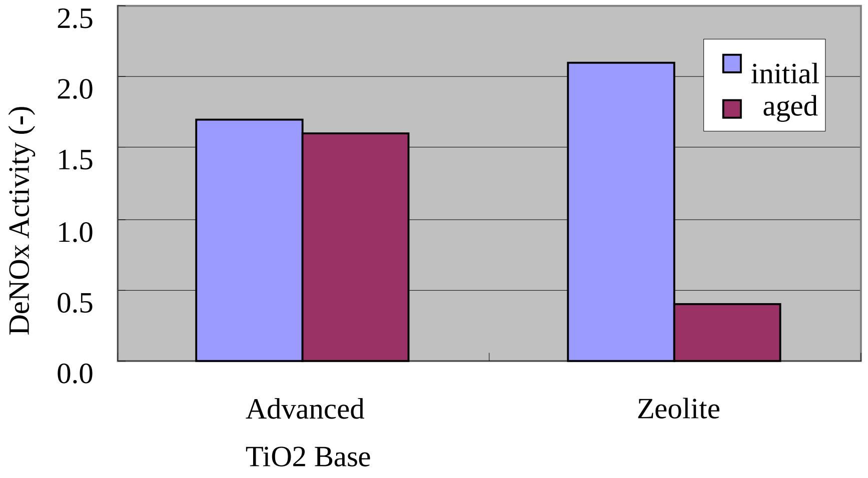


Figure 5 - Accelerated durability test

Figure 6 shows catalyst activity ratio versus gas temperature comparing the conventional type catalyst against the advanced catalyst. The sensitivity to temperature is almost same with the peak point at around 850^0 F. However, the advanced catalyst activity has approximately 1.5 times the activity of the conventional catalyst, which means that it reduces the catalyst volume considerably to minimize potential thermal expansion.

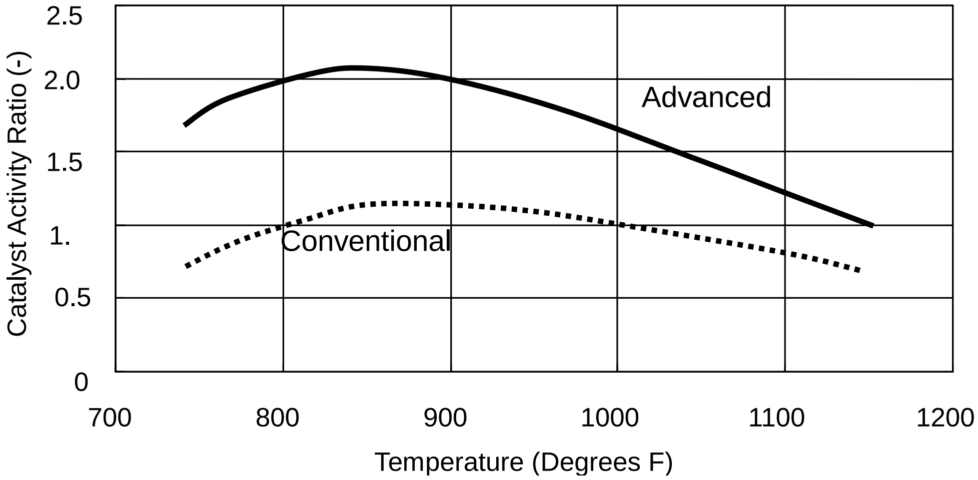


Figure 6 – Catalyst Activity with Gas Temperature

Figure 7 shows the durability of high temperature catalyst. As shown in the figure, performance is satisfactory for over 20,000 operating hours substantiating that the advanced catalyst has sufficient durability for commercial operation.

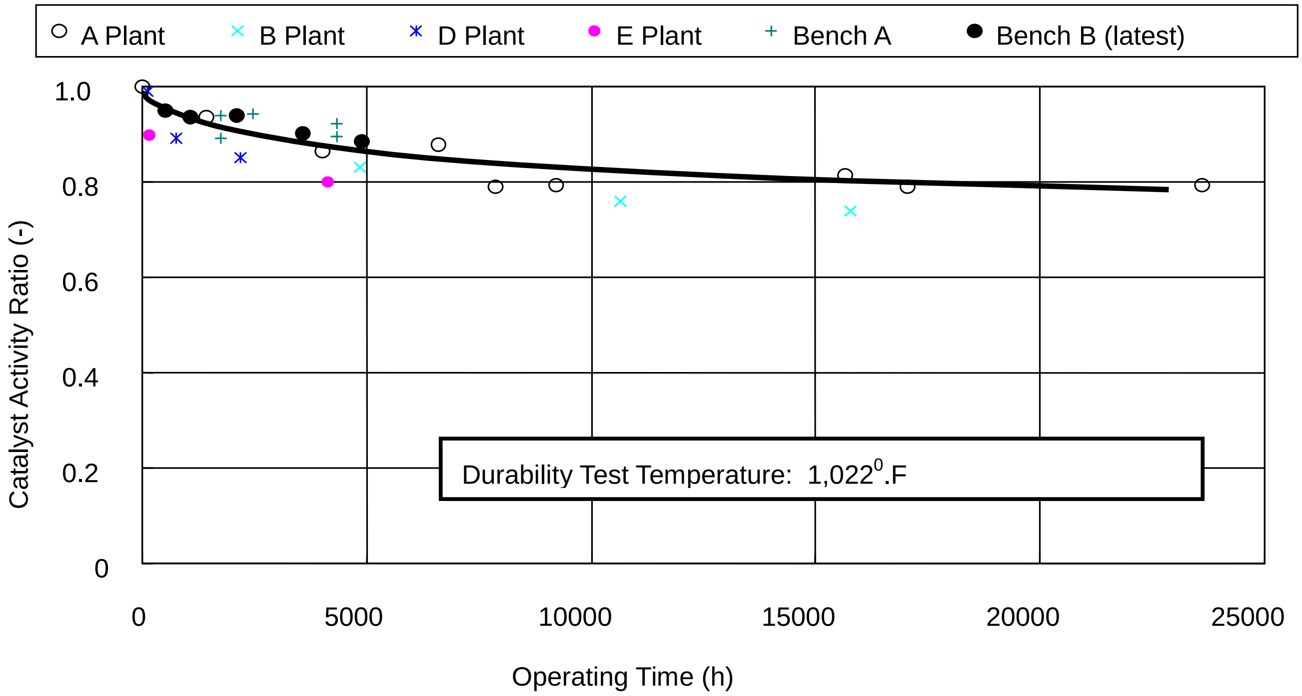


Figure 7 – Catalyst Activity Ratio with Operating Time

CONCLUSIONS

This paper has discribed a new advanced high temperature catalyst developed in the early 1990s for simple cycle applications. This catalyst has sufficient activity packed into a relatively small volume allowing for compact low pressure drop designs. It has considerable experience with proven durability at high temperatures, to 1,100^0 F and is only limited by the increase in ammonia oxidation ragtes with increasing operating temperature.

EXHIBIT 6

Development of the NOXNON 700-HT SCR Catalyst for Simple Cycle Gas Turbine

Presenter: Pete Higgins
Hitachi Zosen Engineering U.S.A. Ltd., 10777 Westheimer Road, Suite 1020, Houston, TX, 77042
E-mail: higgins@hzeu.com; Telephone: (832)204-5743; Fax: (832) 204-5710
Author: Kazuhiro Yano
Masayoshi Ichiki.
Hitachi Zosen Corporation, 2-11, Funamachi, 2-chome, Taisho-ku, Osaka 551-0022, Japan
E-mail: yano_k@hitachizosen.co.jp; Telephone: 011-81-6-6551-9472; Fax: 011-81-6-6551-9906

Summary

Recently, the simple cycle gas turbine has been a fast growing technology to meet peak load requirements in the U.S. In this system, the temperature of the exhaust gas ranges from about 840-1100°F at the inlet of SCR reactor because there is no Heat Recovery Steam Generator (HRSG) as in Combined Cycle applications. In the higher temperature range, the conventional DeNOx catalyst accelerates the combustion of the reducing agent, NH3, resulting in lower DeNOx efficiencies. Therefore the applicable reaction temperature of the conventional catalyst (TiO_2-V-W) was limited to below 420°C.

Hitachi Zosen Corporation (Hitz) has developed the NOXNON700-HT, a catalyst that works within these high temperature conditions. In the application to high temperature SCR, the catalyst is required to have the suppression for NH3 combustion and the strong affinity for NH3 adsorption. According to the increase of the temperature, the amount of the adsorbed NH3 on catalyst becomes smaller because of NH3 desorption, and DeNOx performance goes down.

The improved performance of the our new catalyst is made possible by suppressing the combustion of NH3 in the higher temperature range and substantially increasing the amount of NH3 on the surface of the catalyst, compared with conventional catalysts.

We have initiated testing the new catalyst in a 75000kW simple cycle gas turbine (GE 6FA) in Ibaraki, Japan. The goal of this test is to demonstrate the durability of the new catalyst.

The test indicates that the new catalyst meets durability requirements for commercial high temperature applications.

The new catalyst is also being prototyped in two 6000kw gas engines (exhaust gas temperatures: 450°C to 470°C) at the Kanagawa Plant, Kawasaki City, Japan. In this testing, NOx reduction efficiencies >90% with NH3 slip < 10ppm have been achieved.

END

Hitz
Hitachi Zosen

Development of NH3-SCR Catalyst for Simple Cycle Gas Turbine

Pete Higgins, P.E.
Hitachi Zosen Engineering, USA
Houston, TX

Kazuhiro Yano
Masayoshi Ichiki
Hitachi Zosen Corporation
Osaka, Japan

Overview

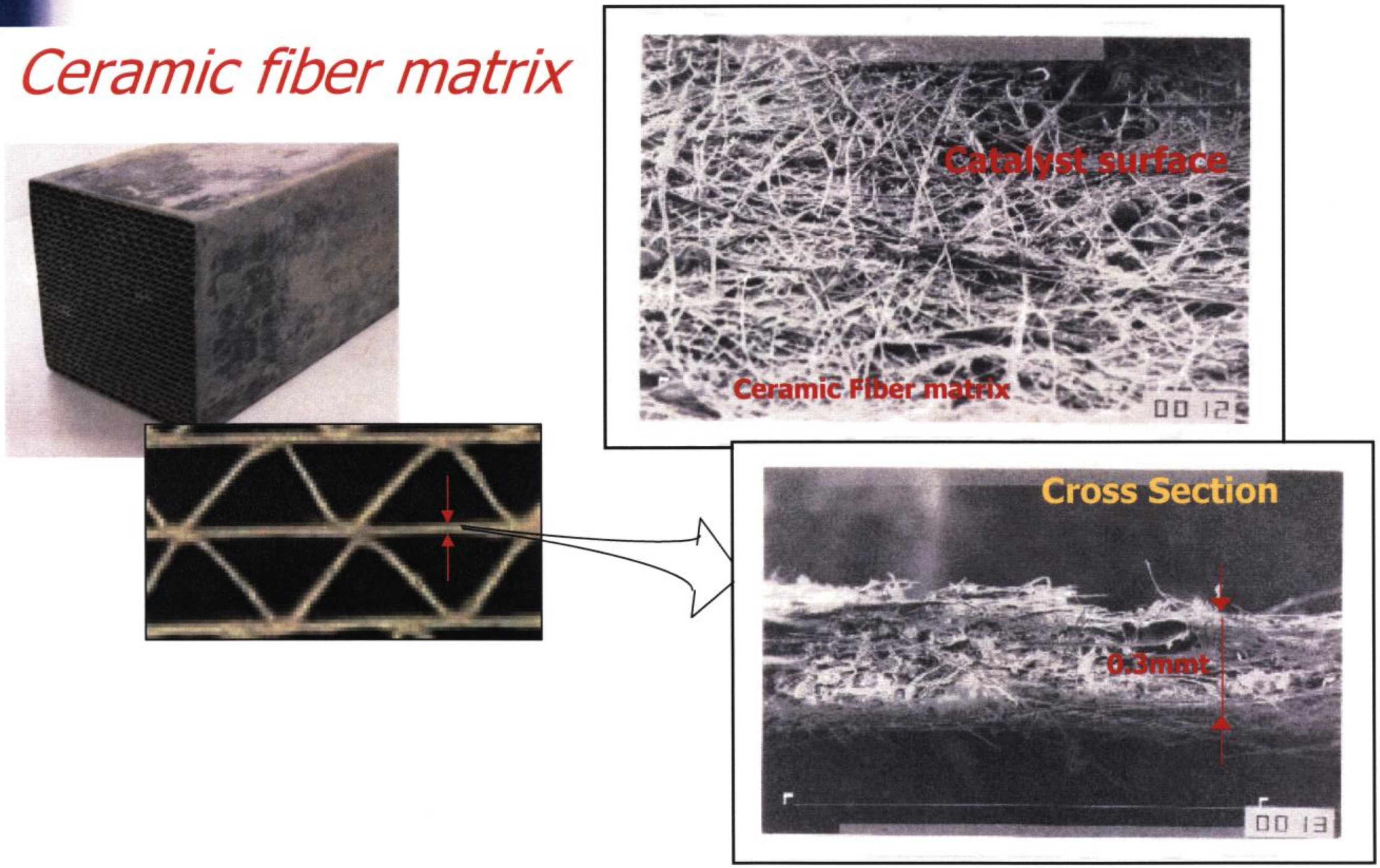
- SCR Mechanisms Review
- Conventional SCR Catalyst Composition/Behavior
- Simple Cycle Performance Requirements
- NOxNON 700-HT Catalyst
    - Performance
    - Durability
- Plant Experience
- Summary

Conventional SCR Catalyst

- Heterogeneous, Supported Metal Catalyst
- Support material consists of SiO_2, Al_2O_3 or other inert porous material.
- Support material is impregnated with Active Metal Oxides; TiO_2, V_2O_5, WO_3, MoO_3 which catalyze NO_x conversion.

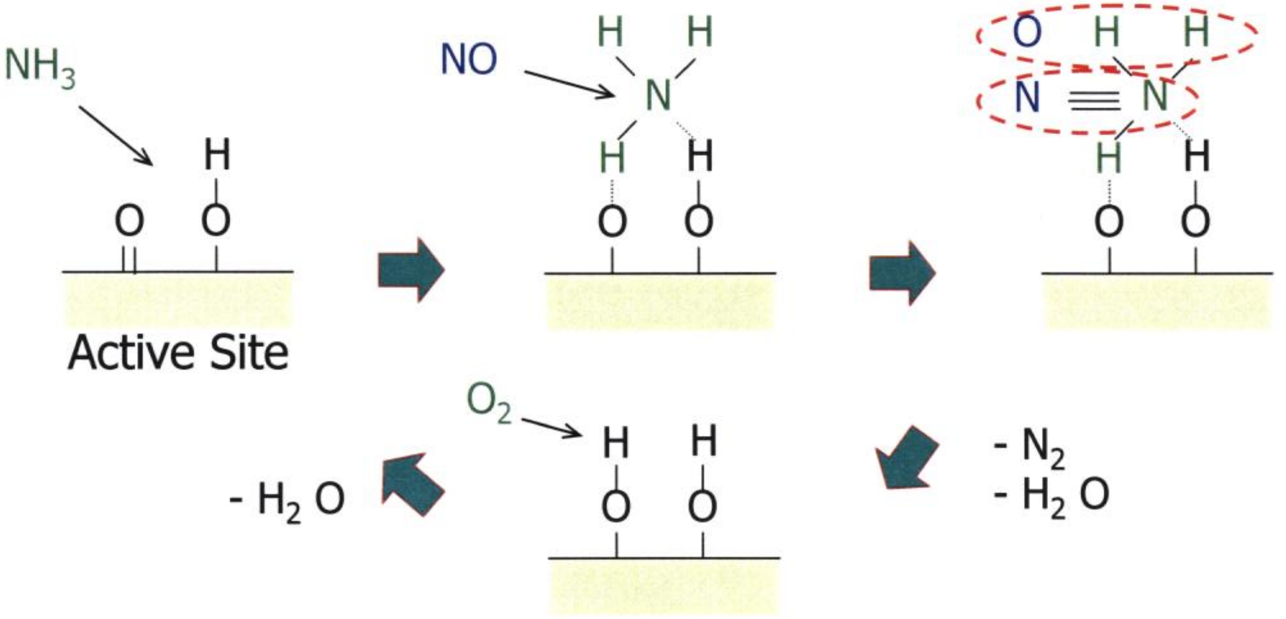
Catalyst Structure

Ceramic fiber matrix

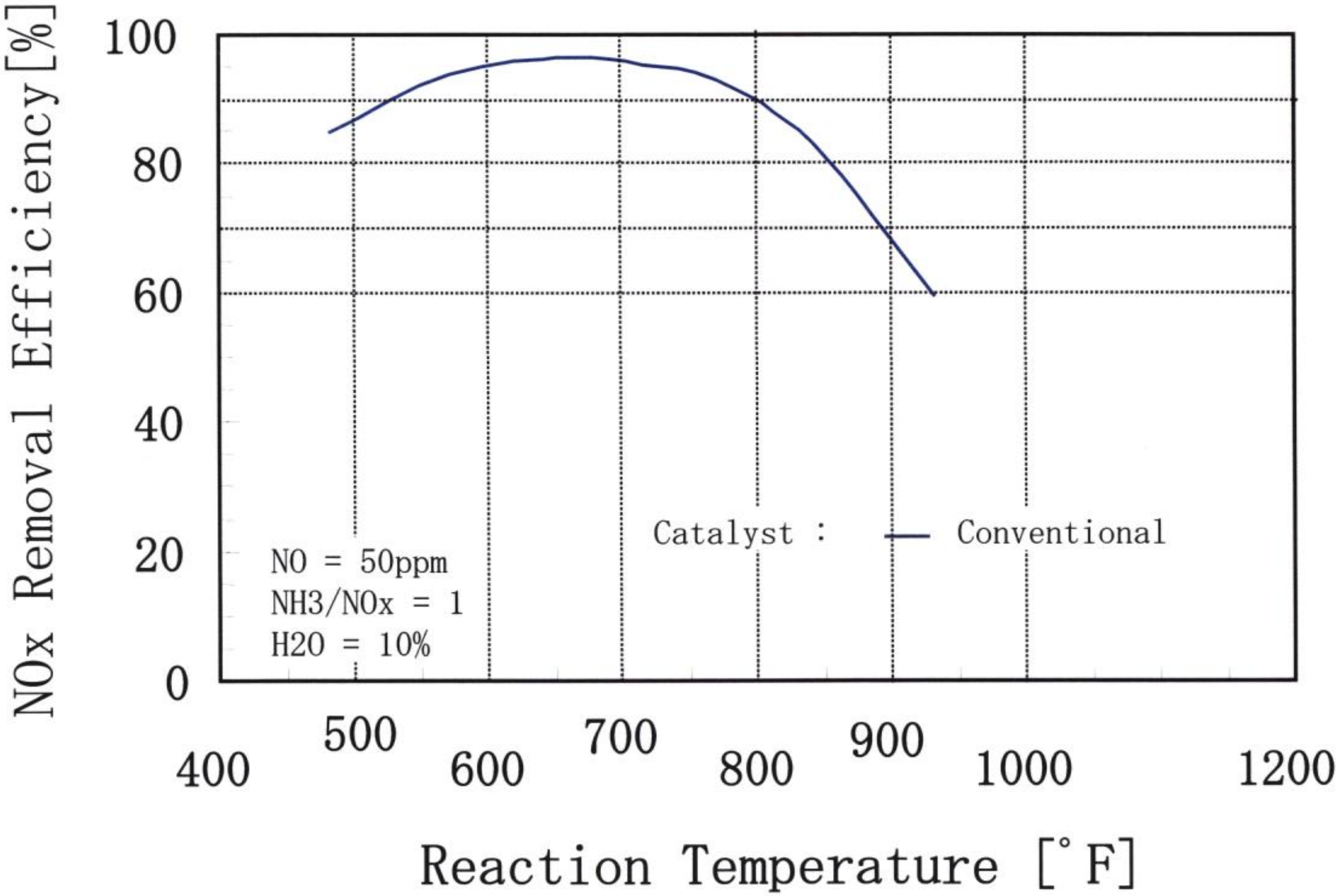


SCR Mechanism (Eley-Rideal Model)

1. NOx and NH_3 diffusion to catalyst surface
2. NH_3 adsorption at active site (${NH_4}^+$ formation)
3. Reaction between ${NH_4}^+$ and NOx
4. Regeneration of active site (to initial state)



Conventional Catalyst Performance



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Hitachi Zosen

Simple Cycle Operation

Features are…

- High temperature

  without HRSG

  Range : 840 – 1122° F
- Daily Start up & Shut down

  Ramp Rate @ GT Outlet : > 900° F/min

  (GE LM-6000PC)

Hitz
Hitachi Zosen

Catalytic Behavior in High Temperature

- NH_3 Adsorption Low at High Temperature

  NH_3 equilibrium balance on catalyst:

  Desorption > Adsorption

- NH_3 Combustion at High Temperature

  $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$ on catalyst:

  Active sites do not promote NOx conversion and produce NO

Hitz
Hitachi Zosen

High Temperature Catalyst Design

To Counteract NH3 Desorption…

There must be strong interaction between NH3 and the catalyst

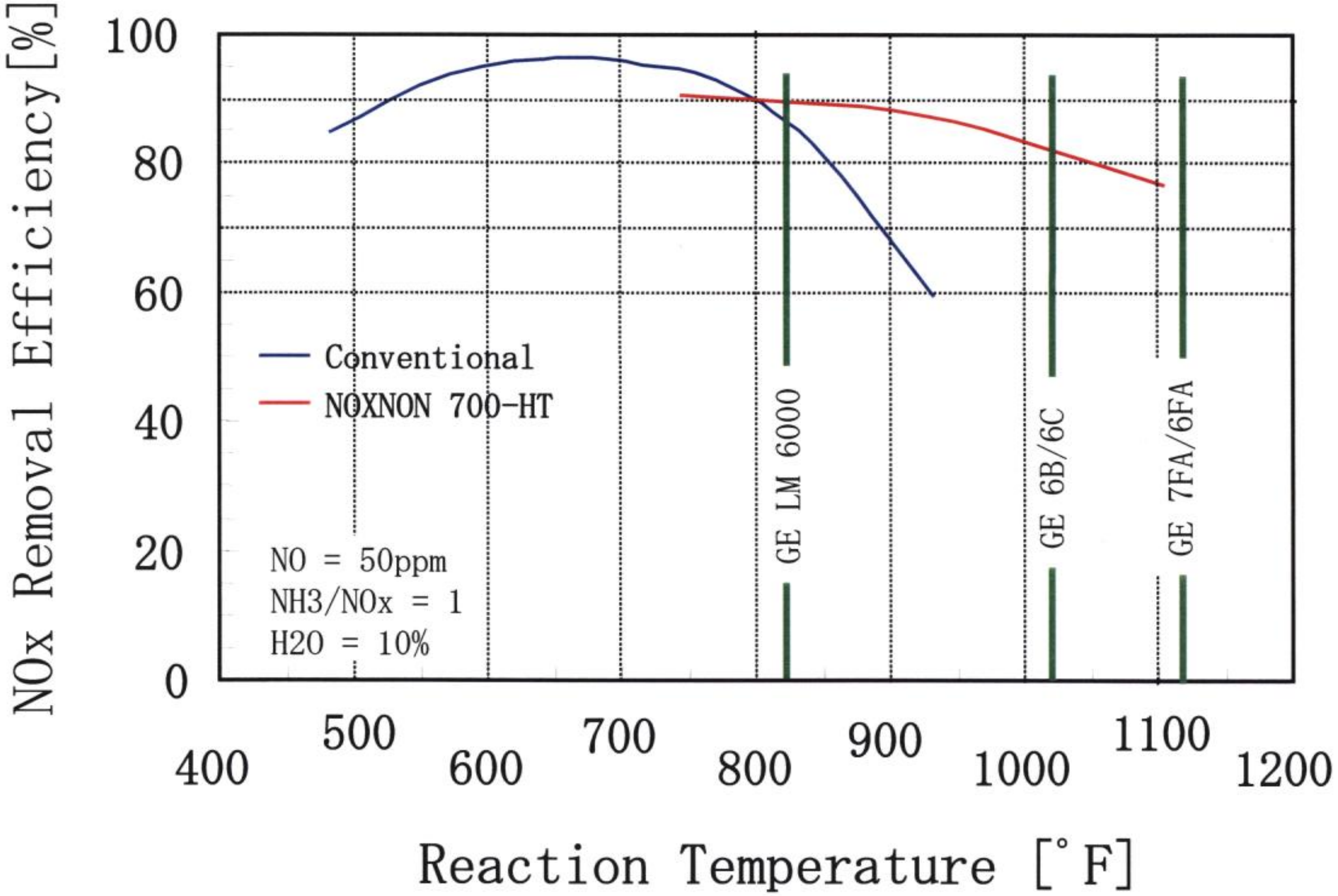
Acidic chemical composition is used in the catalyst

To Suppress NH3 combustion…

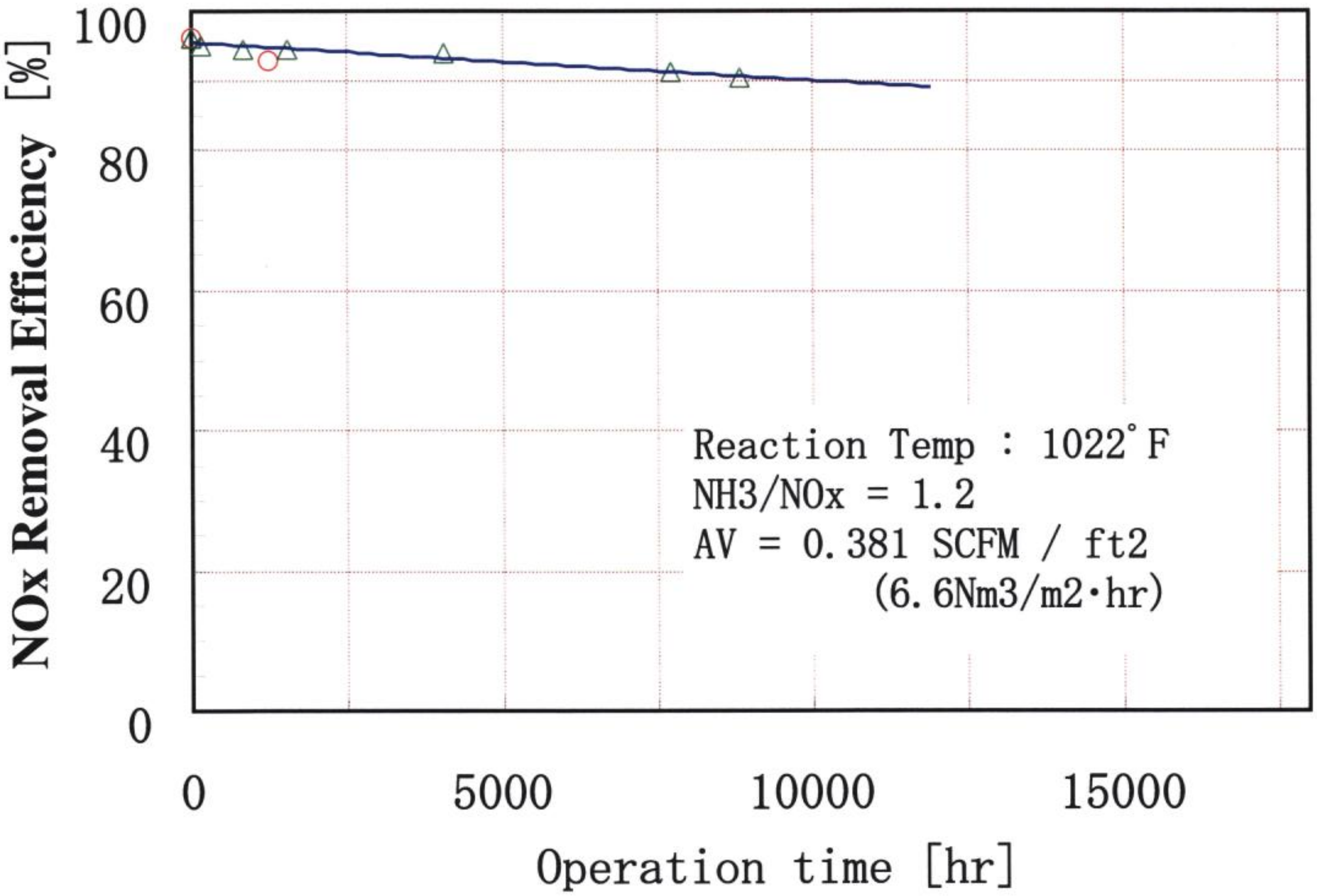
Metal oxides with lower oxidation activity must be chosen

Optimum chemical formulation is used in the catalyst

NOxNON 700-HT Performance



Catalyst Performance



Catalyst Durability

Catalyst Long Term Performance is affected by:

1. High Temperature Sintering

   Sintering causes micropore shrinkage on the surface of the TiO2 crystal, thereby reducing active site availability.

Catalyst Structural Strength is affected by:

2. Thermal Shock of Startup/Shutdown

   Thermal stress can cause cracking in catalyst support/substrate. This effect is minimized in ceramic fiber structures.

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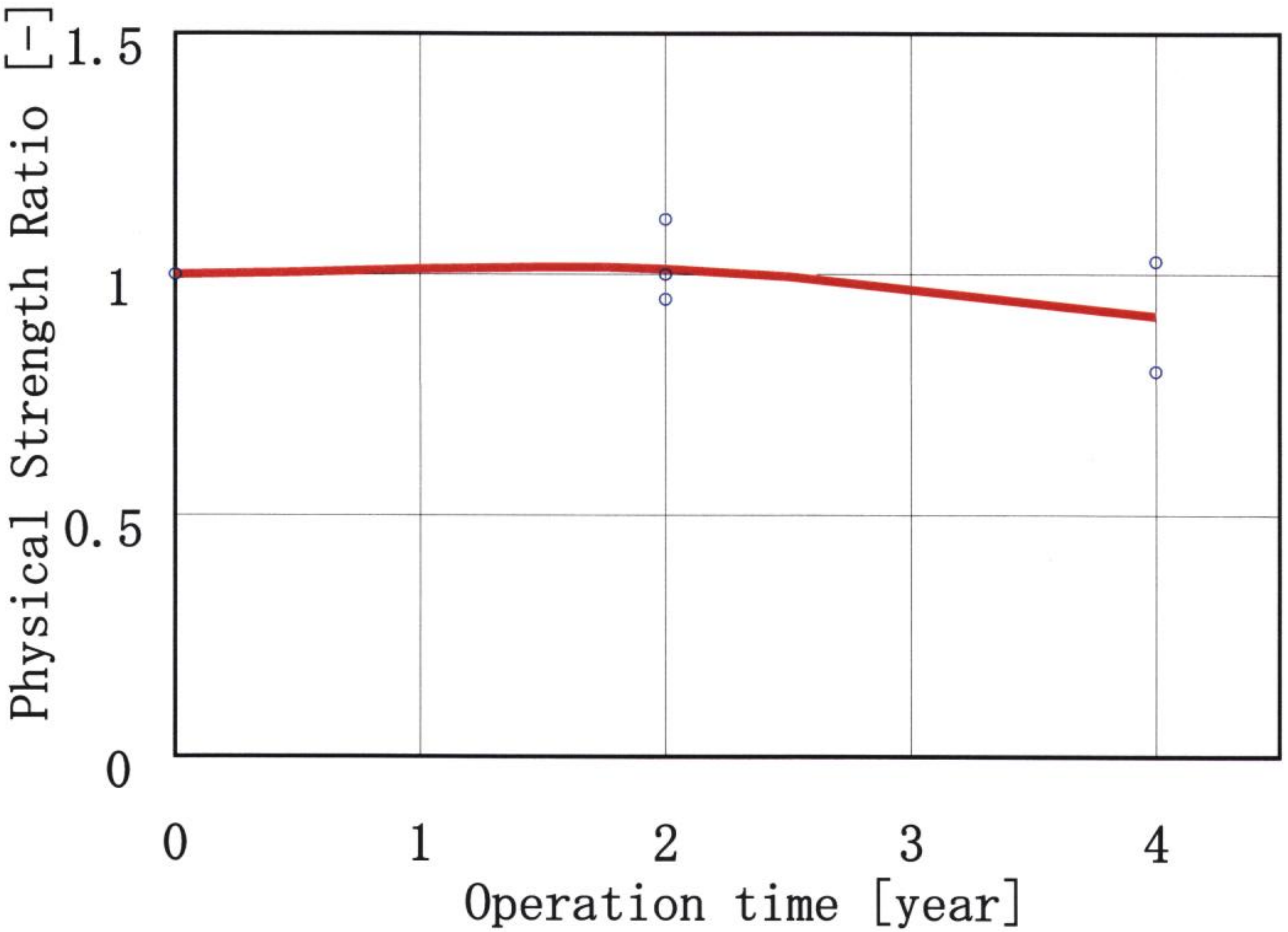
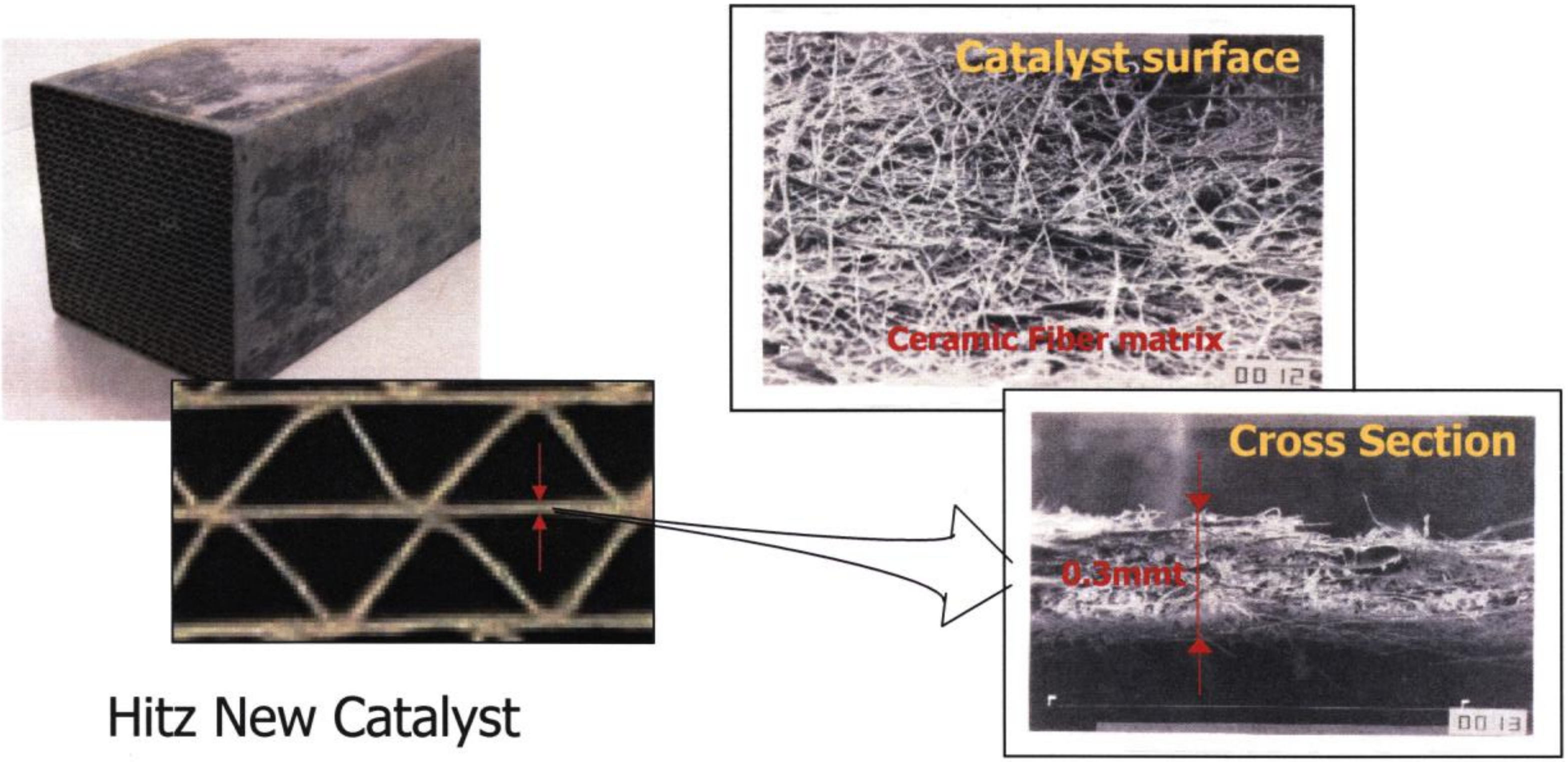
Physical strength of Catalyst Unit



Catalyst Structure

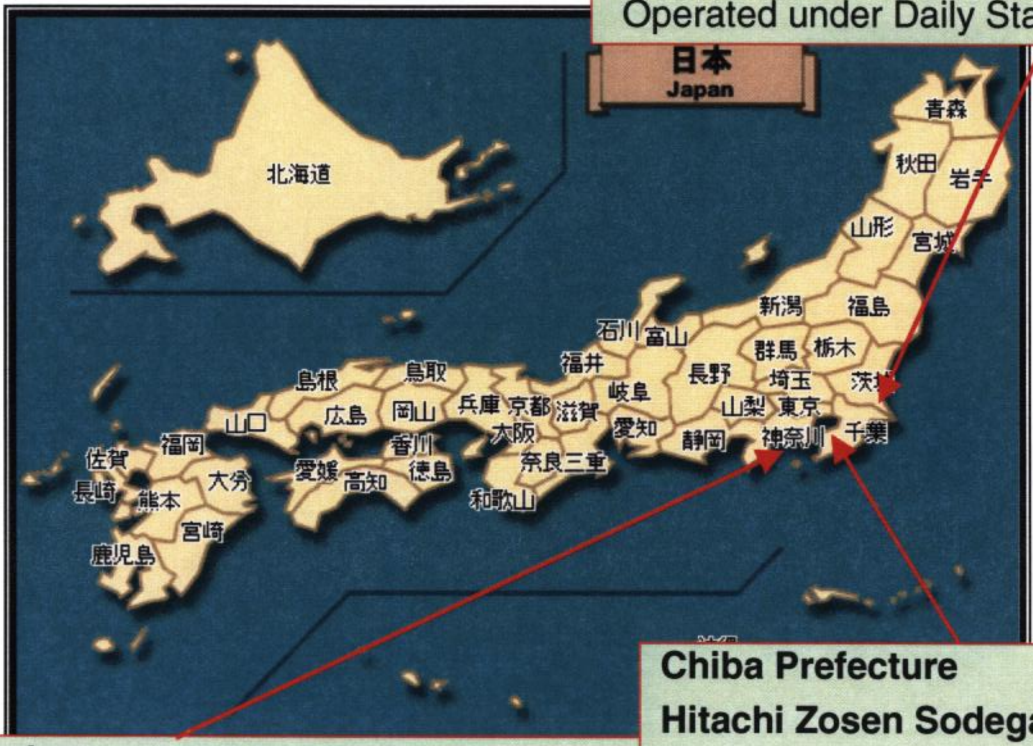
Ceramic fiber matrix structure



Hitz New Catalyst

SEM of Catalyst surface/cross section

Location of Plant



Ibaraki Prefecture

Hitachi Zosen Ibaraki-City Power Plant

NOXNON700-HT Now being Tested in GE-F6A

Operated under Daily Stat-Up /Down at 1094F

Chiba Prefecture

Hitachi Zosen Sodegaura-City Power Plant

GE-F9 x14trains. Tested NOXNON700-HT for 4 years

Kanagawa Prefecture

Hitachi Zosen Kawasaki-City Manufacturing Plant

First Commercial Application of NOXNON700-HT Now Operational.

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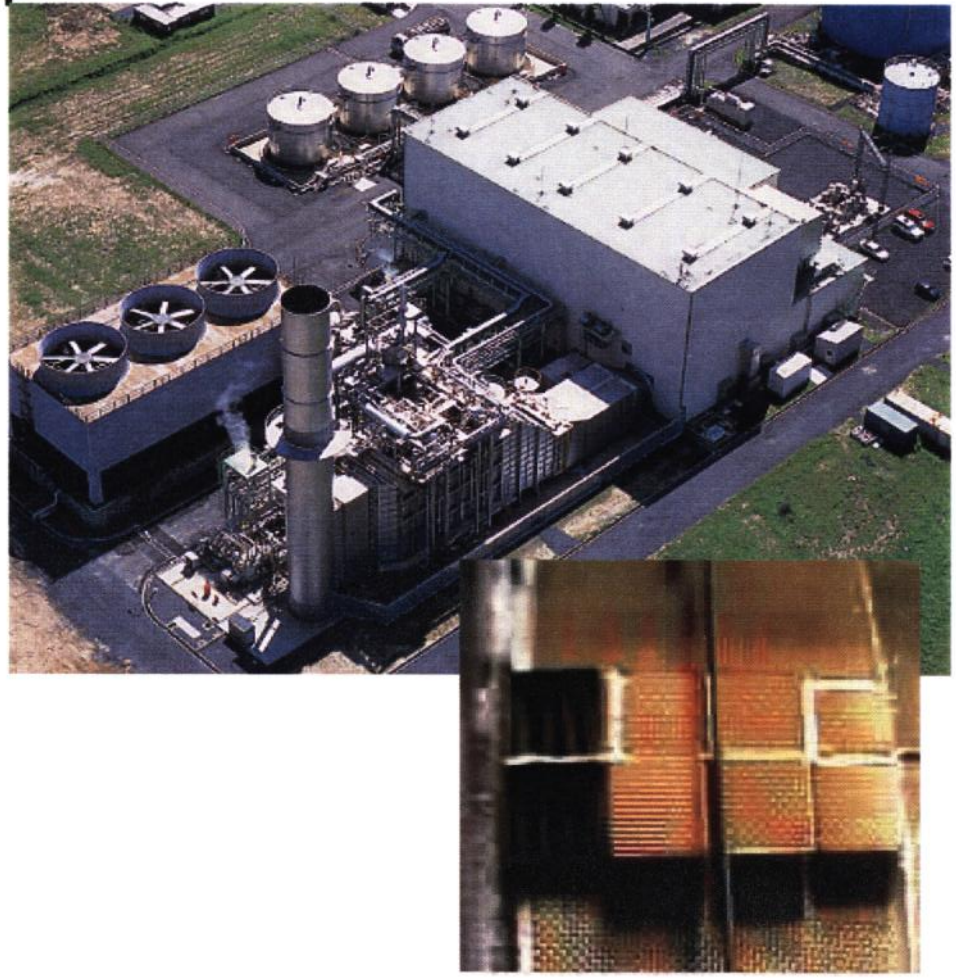
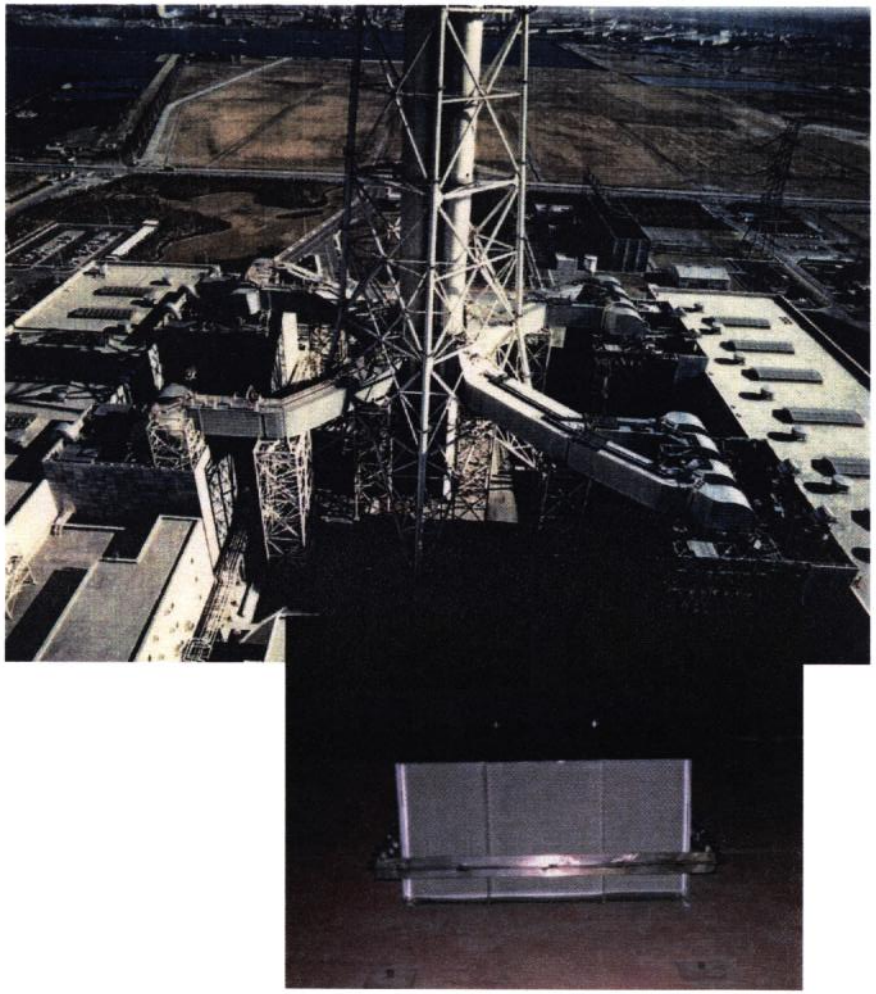
Commercial Plant



Location : Ibaraki, Japan
Gas Turbine : GE F6FA
Gas Temp. : 1094 °F
Operation Mode : DSS
Operation Period : 1year

Commercial Plant



Location : Chiba, Japan

Gas Turbine : GE F9E

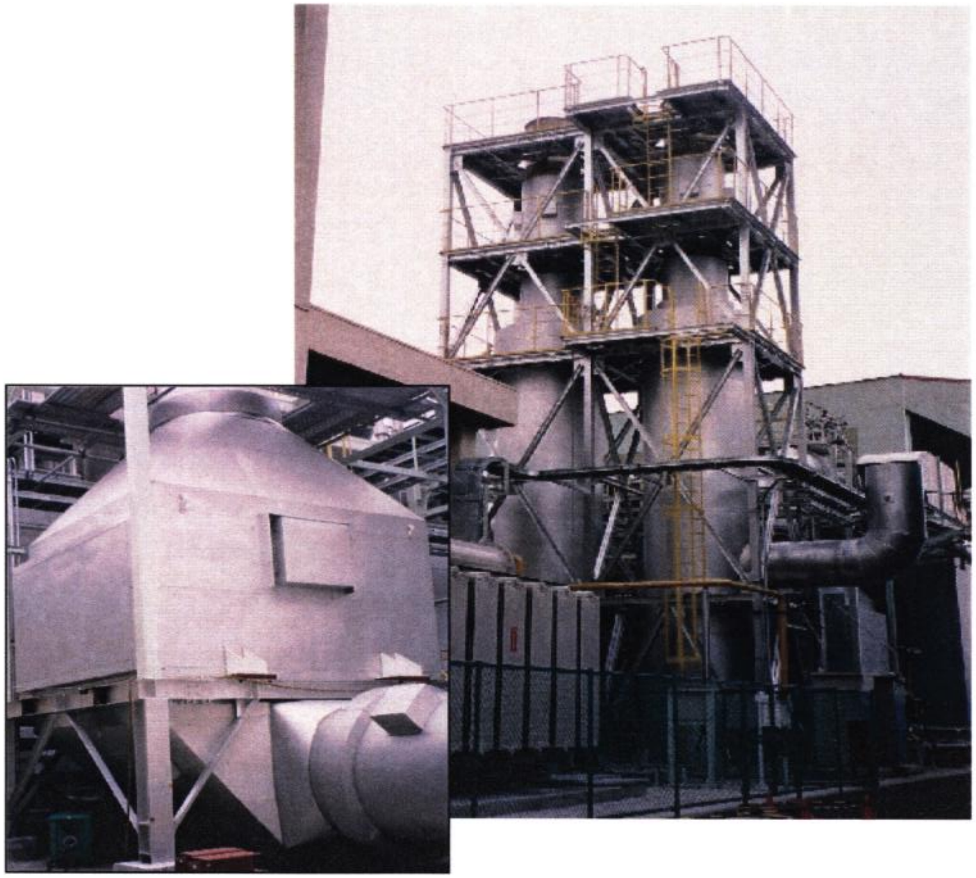
Gas Temp. : 1022° F

Operation Mode : DSS

Operation Period : 4 years

For various application

Gas Engine Power Plant



Location : Kawasaki, Japan

Gas Engine : WARTSILA

１８V３４SG

6000kW x2

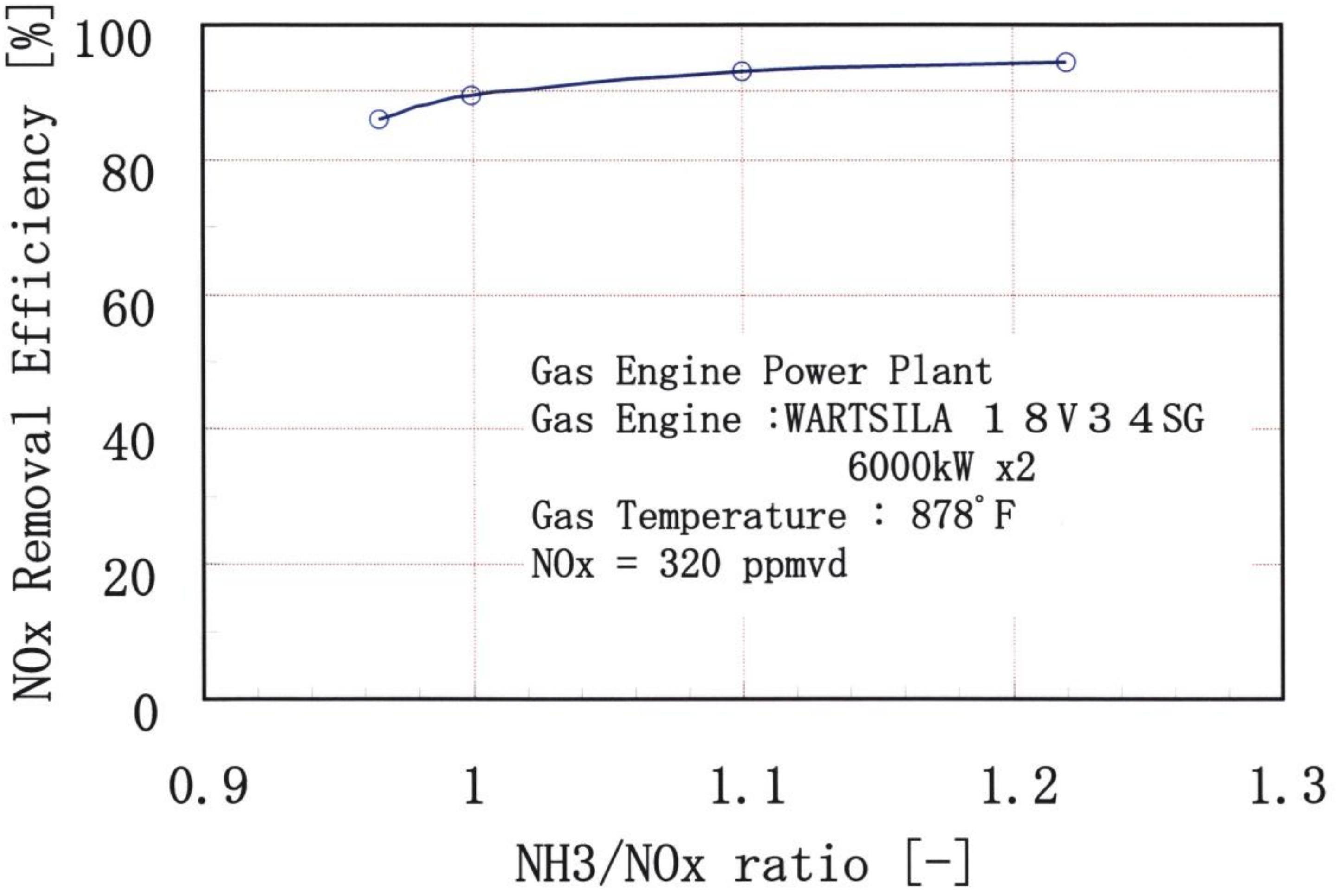
Gas Temp. : 878 ° F

Operation Mode : DSS

Operation Period : 6 months

Hitz
Hitachi Zosen

Performance of Gas Engine Power Plant



Summary (1)

Hitachi Zosen has developed a high temperature SCR catalyst for use in Simple Cycle applications.

The new catalyst, called NOXNON 700-HT has minimal high temperature NH3 oxidation and an increased affinity for NH3 over standard medium temperature catalysts.

Summary （2）

Extensive field testing at 3 different locations in Japan indicates the following:

The DeNOx efficiency of the NOXNON 700-HT is over 90% efficiency for NH3/NOx mole ratios >1.0.

Catalyst durability testing performed over 3 years indicates the NOXNON 700-HT has the capability to withstand thermal stress of high temperature operation and cyclic stresses of startup and shutdown in simple cycle application as proven in material strength testing.

The decrease in catalyst efficiency measured at a gas temperature of 1022 °F is < 4% for 8,000 hrs operation.

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RETURN TO MAIN MENU SCREEN

EXHIBIT 7

HALDOR TOPSØE

Haldor Topsoe, Inc.
17629 El Camino Real
Suite 300
Houston, Texas 77058
www.topsoe.com

Tel: (281) 228-5000
Fax: (281) 228-5019

December 23, 2013

Mr. Tony Licata
Licata Energy and Environmental Consulting, Inc.
345 Concord Road
Yonkers, NY 10170

Dear Tony,

Recently I became aware of concerns associated with the use of selective catalyst reduction (SCR) on simple cycle gas turbines utilizing large frame engines such as the GE 7FA and Siemens 501 FD2. Haldor Topsoe, (HTI) has experience with SCR on many types of gas turbine engines in simple cycle mode as well as combined and cogeneration arrangements.

Though HTI doesn't have experience with any large frame machines with SCR, we do have a large number of aeroderivative engines with SCR where many use tempering air to control flue gas temperature. HTI feels that SCR installed on large frame simple cycle gas turbines is a viable technology but does require good engineering and modelling to insure success.

In reality, on natural gas and ULSD fired applications, SCR catalyst does not care about the source of flue gas it is treating. What is important is that the ammonia to NOx distribution at the face of the catalyst is sufficiently uniform to support the required NOx removal efficiency and ammonia slip. One advantage of the large frame units is that the uncontrolled NOx emission rate is generally lower than the uncontrolled rate on aeroderivative engines, thus the required NOx removal efficiency to reach an outlet NOx concentration of either 2.5 ppm or 2.0 ppm is generally lower. A lower NOx removal efficiency requires less uniform ammonia to NOx distribution at the catalyst face to achieve the required NOx removal while controlling ammonia slip. In fact, for a NOx removal efficiency of about 75% the required ammonia to NOx maldistribution to achieve an end of life ammonia slip of 5 ppm is greater than 20% RMS.

HTI has considerable SCR experience with flue gas temperatures up to 900°F. By reducing the flue gas temperature of the large frame machine to about 850°F using tempering air, HTI's medium high temperature catalyst can be used. The challenge is mixing of the tempering air to achieve not only a uniform temperature distribution but also uniform ammonia to NOx distribution at the catalyst face. Remember that poorly mixed tempering air also creates poor ammonia to NOx distribution by diluting the NOx concentration in areas where tempering air is over abundant.

Another concern is CO catalyst that can impede the mixing of tempering air before complete mixing is achieved. For these applications, the use of a dual function SCR/CO catalyst both installed together in one module may be the best option. The HTI SCR/CO dual function catalyst is installed in the usual location of the SCR catalyst and allows for the use of liquid ammonia injection at the engine exhaust where unobstructed mixing of the ammonia, tempering air and flue gas can occur. With any arrangement, HTI recommends the installation of a high resolution permanent sample grid at the exit of the SCR or SCR/CO catalyst. This grid is the only way to get an accurate measurement of the real ammonia to NOx distribution, as well as the NOx distribution at the catalyst face. The grid is mandatory for troubleshooting or optimization of the AIG or ammonia injection system.

HTI believes that excellent SCR performance is possible on large frame simple cycle units achieving 2.0 ppm outlet NOx with no more than 5 ppm ammonia slip during the guarantee life. HTI also believes that this same performance can be attained while firing either natural gas or ULSD fuels.

Regards,

HALDOR TOPSOE, INC.

Wayne S Jones
Sales Manager
Power Generation

WSJ/jlt/33/dec13

EXHIBIT 8

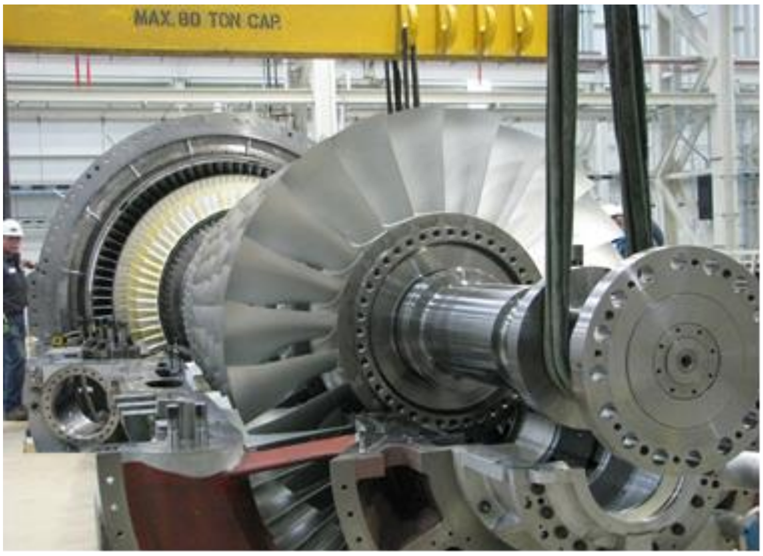
Erlangen, September 30, 2013

Siemens gas turbine STG6-5000F demonstrates 25 ppm NOx emissions on fuel oil

The Siemens gas turbine SGT6-5000F sets a new benchmark in the industry by demonstrating 25 ppm NOx emissions on fuel oil. The current industry standard is 42 ppm for other OEM F-Class gas turbines. In order to provide the highest power output for this type of turbine and at the same time lowest emissions on fuel oil Siemens invested in research and development of the SGT6-5000F combustion system with water injection. After extensive testing under real world conditions, this outstanding result has been achieved at the Elk River Peaking Station in Minnesota, USA, in conjunction with Great River Energy. This turbine with the new capability is already commercially available.

“The SGT6-5000F is an extremely well-proven turbine in the US 60 Hz market with more than 270 units already in commercial operation worldwide and more than nine million cumulative hours of reliable operation. This new emissions level has strategic importance to our customers, and Siemens will continue to innovate and provide leading technology to enable their continued success”, said John Wilson, Head of Sales for Gas Turbine Packages in the Americas Region.

“Great River Energy has a history of collaborative research on emission reduction projects, and this is another example resulting in measurable emission reductions,” said Michael Shevich, combustion turbine supervisor, Great River Energy.



Gas turbine SGT6-5000F

The picture shows the Siemens gas turbine SGT6-5000F. The turbine has an electrical power output of up to 232 MW and achieves maximum cost efficiency whether in peak-, intermediate-, or base-load duty.

Contact for journalists:
Siemens AG, Media Relations
Gerda Gottschick, phone: +49 9131 18-85753
E-mail: gerda.gottschick@siemens.com

This press release and a press picture can be found at
www.siemens.com/press/pi/EFP201309067e
For further information on Siemens gas turbine SGT6-5000F, please see
www.siemens.com/energy/SGT6-5000F
Follow us on Twitter at: www.twitter.com/siemens_press

The **Siemens Energy Sector** is the world's leading supplier of a broad spectrum of products, services and solutions for power generation in thermal power plants and using renewables, power transmission in grids and for the extraction, processing and transport of oil and gas. In fiscal 2012 (ended September 30), the Energy Sector had revenues of EUR27.5 billion and received new orders totaling approximately EUR26.9 billion and posted a profit of EUR2.2 billion. On September 30, 2012, the Energy Sector had a work force of almost 86,000. Further information is available at: www.siemens.com/energy.

EXHIBIT 9

From: Marini, Bonnie D (E P ES SGAM MK&S PLMK)
[mailto:bonnie.marini@siemens.com]
Sent: Monday, November 11, 2013 9:36 AM
To: Anthony Licata
Cc: Burns, Dan D (E P ES SGAM NA)
Subject: RE: Siemens 5000F5 turbines

Hi Tony,

As discussed, for the SGT6-5000F we can offer an option which would meet the requirement of 45 second fuel transfer.

I have coped Dan Burns so you have his contract information. He will follow up on the other info discussed.

Best Regards,

Bonnie

From: Anthony Licata [mailto:tonylicataleec@aol.com]
Sent: Monday, November 11, 2013 8:18 AM
To: Marini, Bonnie D (E P ES SGAM MK&S PLMK)
Subject: Siemens 5000F5 turbines

Bonnie

Please call me as soon as possible.

Tony Licata
Licata Energy & Environmental Consulting, Inc
345 Concord Road
Yonkers, NY 10170
Phone 914-779-3451
Cell 914-672-5205
Email TonyLicataLEEC@aol.com<mailto:TonyLicataLEEC@aol.com>

EXHIBIT 10

The Avogadro Group, LLC

SOURCE TEST REPORT
2013 EMISSION COMPLIANCE TESTS AND CEMS RATA AT THE MARSH LANDING GENERATING STATION ANTIOCH, CALIFORNIA

Prepared For:

KIEWIT POWER CONSTRUCTORS, CO.
9401 Renner Boulevard
Lenexa, Kansas 66219

For Submittal To:

BAY AREA AIR QUALITY MANAGEMENT DISTRICT
CALIFORNIA ENERGY COMMISSION

Prepared By:

THE AVOGADRO GROUP, LLC
2825 Verne Roberts Circle
Antioch, California 94509

(877) 602-1023

June 6, 2013

REVIEW AND CERTIFICATION

All work, calculations, and other activities and tasks performed and documented in this report were carried out by me or under my direction and supervision. I hereby certify that to the best of my knowledge, Avogadro operated in conformance with the requirements of ASTM D7036-04 during this test project.

Name: Ian DeVivi

Title: Project Manager

Sign: Ian DeVivi

Date 06/14/2013

I have reviewed, technically and editorially, details, calculations, results, conclusions, and other appropriate written materials contained herein. I hereby certify that to the best of my knowledge the presented material is authentic and accurate and conforms to the requirements of ASTM D7036-04.

Name: Kevin J. Crosby

Title: Technical Director

Sign: Kevin J. Crosby

Date: 06/14/2013

Init. ______

Init. ______

SUMMARY INFORMATION

Source and Contact Information

Source Location:	Marsh Landing Generating Station 3201-C Wilbur Avenue Antioch, California 94509
Project Contact:	Mr. Doug King
Title:	Startup Manager, Marsh Landing Generation Station, Kiewit Power Constructors, Co.
Telephone:	925-331-1350
Mobile:	913-945-0652
Project Contact:	Mr. Tom Bertolini
Title:	Senior Environmental Engineer NRG Energy
Telephone:	925-427-3503
Mobile:	925-324-3503
Regulatory Agency:	Bay Area Air Quality Management District (BAAQMD) California Energy Commission (CEC)
Units:	Four Siemens SGT6-5000F gas turbine engines operated in simple cycle identified as units 1 and 2 (NST-2800) and units 3 and 4 (NST-2801)
Purpose:	Conduct required source testing to demonstrate compliance with emission limitations specified in BAAQMD Authority to Construct permit, Application No. 18404 for each turbine
Test Methods:	EPA Methods 3A, 7E, 10, 19, 18, TO-12, TO-15 and CTM-13 CARB Method 5, 429 and 430, BAAQMD Method ST-1B ASTM Method D-5504 (fuel sulfur)

Testing Company Information

Testing Firm:	The Avogadro Group, LLC 2825 Verne Roberts Circle Antioch, California 94509	(Accreditation ASTM D-7036) (CARB Certified)
Contacts:	Mr. Ian DeVivi Project Manager	Mr. Kevin Crosby Client Account Manager
Telephone:	(925) 680-9020	(925) 680-4337
Mobile:	(925) 301-7755	(925) 381-9635
Test Dates:	January 14 to April 21, 2013	

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APPENDICES

APPENDICES (Continued)

APPENDICES (Continued)

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SECTION 1.0

INTRODUCTION

The Avogadro Group, LLC (Avogadro) was contracted by Kiewit Power Constructors, Co. (Kiewit) to perform a series of source emission tests at the Marsh Landing Generating Station in Antioch, California. The testing program was performed to determine compliance with the emission limitations of the Authority to Construct Permit (Application No. 18404, Plant No. 19169) issued by the Bay Area Air Quality Management District (BAAQMD), and the Revised Staff Assessment (Docket Number 08-AFC-03) issued by the California Energy Commission (CEC).

Emissions were measured from four gas turbines used as peaking units for electrical generation identified as Units 1 and 2 (NST-2800) and Units 3 and 4 (NST-2801). Some of the test runs were also used to provide a relative accuracy test audit (RATA) of the continuous emission monitoring system (CEMS) on each unit, which is presented in a separate report.

The testing program was conducted by Ian DeVivi, Chris Crowley, Kris Huckabay, Todd Smith, Jerry McDonald, Jose Orozco, Neal Ohlenfdorf and Brian Do of Avogadro. The testing program was conducted during multiple mobilizations from January to April 2013. The process operations were coordinated by Doug King of Kiewit and Tom Bertolini of NRG. The tests were conducted according to a test plan that was submitted to the BAAQMD on December 7, 2012. Avogadro performed the tests to measure the following emission parameters, according to the BAAQMD permit conditions, with the CEC Conditions of Certification numbers shown in parentheses:

Condition 10 (AQ-10) – Test ***all four*** Gas Turbine units to determine compliance with the limits of condition 17 (AQ-17) **(as shown below for conditions 27 and 28)**.

The tests will also include testing of ***all four*** Gas Turbine units during three **startups** and three **shutdowns** for the following emissions to determine compliance with the limits of condition 18 (AQ-18):

- NO_X, CO (also concentrations of O_2 and CO_2)
- Precursor Organic Compounds (POC), methane and ethane

Condition 27 (AQ-27) – Test ***all four*** Gas Turbine units at **maximum load** and at **minimum load** for the following emissions to determine compliance with the limits of condition 17e (AQ-17e) and to determine the correlation of ammonia emission concentrations with the gas turbine heat input and ammonia injection rates:

- NH_3

Condition 28 (AQ-28) – Test ***all four*** Gas Turbine units at **maximum load** for the following emissions to determine compliance with the limits in condition 17 (AQ-17) a, b, c, d, f, g, h and i:

- NO_X, CO (also concentrations of O_2 and CO_2)
- Precursor Organic Compounds (POC)
- SO_2
- Particulate Matter (PM_{10} and Total PM including Condensable PM)

Condition 28 (AQ-28) – Test ***all four*** Gas Turbine units at **minimum load** for the following emissions to determine compliance with the limits in condition 17 (AQ-17) c and d:

- CO (also concentrations of O_2 and CO_2)

Condition 30 (AQ-30) - Biennial testing of ***one*** Gas Turbine unit at **maximum load** and at **minimum load** for the following emissions to determine compliance with the limits of condition 23 (AQ-23):

- Benzene
- Formaldehyde
- Specified PAH compounds

Condition 32 (AQ-32) – Test ***two*** of the Gas Turbine units at **maximum load** for the following emissions to determine compliance with the limit in condition 33 (AQ-33):

- Sulfuric Acid Mist (SAM), SO_3 and SO_2 (note that SO_3 and SAM are the gaseous and liquid phases of the same material.

The test results also provide data for use in calculating emission factors as required by permit conditions 25, 26 and 31 (AQ-25, AQ-26 and AQ-31).

Avogadro provided the test personnel and all necessary equipment to measure emissions as outlined in the protocol and subcontracted an analytical laboratory for the fuel sample analysis. Kiewit personnel coordinated the unit operating conditions and provided the process data which are included in this report.

This report presents the test results, descriptions of the testing procedures, descriptions of the facility and the sampling locations, and a summary of quality assurance procedures. The average results are summarized in Tables 1-1 through 1.10. Detailed results for individual test runs can be found in Section 5.0 and in the appendices. The supporting data are provided in the appendices, which include Avogadro's quality assurance procedures and data, accreditation information and CARB certification for source testing, CEMS data, plant process data sheets, sampling data sheets, laboratory reports and spreadsheets.

TABLE 1-1
SUMMARY OF AVERAGE TEST RESULTS GASEOUS EMISSIONS, MINIMUM LOAD MARSH LANDING GENERATING STATION JANUARY - APRIL 2013

Parameter	CTG-1	CTG-2	CTG-3	CTG-4	Permit Limit
Process Data:					
Fuel Flow, scf/hr:	1,392,058	1,385,310	1,397,900	1,395,040	--
Gas turbine gross output, MW:	125	124	128	126	--
Ammonia injection, lb/hr:	150.2	197.3	111.6	197.8	--
Stack Gas Data:					
O_2, % volume dry:	16.29	16.19	16.39	16.00	--
CO_2, % volume dry:	2.70	2.71	2.62	2.86	--
Stack gas flow rate, dscfm:	939,764	912,646	964,151	882,582	--
Carbon Monoxide:					
ppm volume dry:	0.551	0.291	0.274	0.049	--
ppm @ 15% O_2:	0.706	0.364	0.358	0.059	2.0
lb/hr:	2.251	1.154	1.147	0.188	10.0
lb/MMBtu:	0.0016	0.0008	0.0008	0.0001	0.00454
Ammonia:					
ppm volume dry:	2.213	1.997	*0.145*	0.323	--
ppm @ 15% O_2:	2.834	2.501	*0.190*	0.389	10.0

Note: Results shown in italics are below the detection limit, and reported at the detection limit.

TABLE 1-2
SUMMARY OF AVERAGE TEST RESULTS
PM$_{10}$ EMISSIONS, MAXIMUM LOAD
MARSH LANDING GENERATING STATION
JANUARY – APRIL 2013

Parameter	**CTG-1**	**CTG-2**	**CTG-3**	**CTG-4**	**Permit Limit**
Process Data:					
Fuel Flow, scf/hr:	2,092,125	2,035,293	2,041,265	2,062,727	--
Gas turbine gross output, MW:	212	206	206	209	--
Ammonia injection, lb/hr:	218.0	227.1	181.0	263.5	--
Stack Gas Data:					
O$_2$, % volume dry	15.70	15.67	15.71	15.66	--
CO$_2$, % volume dry	3.00	2.98	2.93	3.04	--
Stack temperature, ºF	829.7	819.9	815.7	847.4	--
Moisture content, % by volume	6.25	6.68	6.40	5.70	--
Stack flow rate, dscfm	1,245,253	1,207,435	1,223,152	1,221,182	--
F½ Particulate Matter:					
gr/dscf	0.0000**	0.0000**	0.0001**	0.0001**	--
lb/hr	0.30**	0.48**	0.65**	1.35**	--
lb/MMBtu	0.0001**	0.0002**	0.0003**	0.0006**	--
B½ Particulate Matter:					
gr/dscf	0.0001**	0.0001**	0.0002	0.0001	--
lb/hr	0.64**	1.04**	2.22	1.24	--
lb/MMBtu	0.0003**	0.0005**	0.0011	0.0006	--
Total Particulate Matter (PM$_{10}$):					
gr/dscf	0.0001**	0.0001**	0.0003**	0.0002**	--
lb/hr	0.95**	1.52**	2.87**	2.59**	9.0
lb/MMBtu	0.0004**	0.0007**	0.0014**	0.0012**	--
Accuracy ±0.0002 gr/dscf					--

Note: The tests were conducted using EPA Methods 5 and 202, and the total PM has been reported as representative of PM$_{10}$ emissions. Results have been reported according to the BAAQMD guidance "QAPP" document. Therefore, the following data tags have been used:

The "<" symbol indicates that the analyte was measured in all fractions below the limit of detection and is reported at the LOD.

The ** symbol indicates that the analyte was Below the limit of detection in some, but not all sample fractions.

TABLE 1-3
SUMMARY OF AVERAGE EMISSION TEST RESULTS GASEOUS EMISSIONS, MAXIMUM LOAD MARSH LANDING GENERATING STATION JANUARY – APRIL 2013

Parameter	CTG-1	CTG-2	CTG-3	CTG-4	Permit Limit
Process Data:					
Fuel Flow, scf/hr:	2,099,137	2,047,513	2,003,292	2,071,500	--
Gas turbine gross output, MW:	212	208	200	210	--
Ammonia injection, lb/hr:	222.4	229.0	190.0	269.9	--
Stack Gas Data:					
O_2, % volume dry:	15.69	15.72	15.67	15.70	--
CO_2, % volume dry:	3.00	3.00	3.04	3.03	--
Stack gas flow rate, dscfm:	1,247,023	1,225,967	1,190,812	1,234,594	--
Carbon Monoxide:					
ppm volume dry:	0.18	0.10	0.07	0.09	--
ppm @ 15% O_2:	0.20	0.11	0.08	0.11	2.0
lb/hr:	0.971	0.523	0.380	0.503	10.0
lb/MMBtu:	0.0005	0.0002	0.0002	0.0002	0.00454
Nitrogen Oxides:					
ppm volume dry:	1.87	1.91	1.92	1.58	--
ppm @ 15% O_2:	2.12	2.17	2.16	1.79	2.5
lb/hr as NO_2:	16.680	16.673	16.277	13.94	20.83
lb/MMBtu as NO_2:	0.0078	0.0079	0.0079	0.0066	0.00946
Sulfur Oxides (from fuel sulfur)**:**					
fuel sulfur gr/100 scf:	0.158	0.086	0.107	0.135	--
stack ppm volume dry as SO_2:	0.08	0.04	0.05	0.06	--
ppm @ 15% O_2 as SO_2:	0.09	0.05	0.06	0.07	--
lb/hr as SO_2:	0.945	0.502	0.612	0.798	6.21
lb/MMBtu as SO_2:	0.0004	0.0002	0.0003	0.0004	0.0028
Ammonia:					
ppm volume dry:	2.065	1.488	0.309	2.298	--
ppm @ 15% O_2:	2.336	1.695	0.349	2.611	10.0
Precursor Organic Compounds:					
ppm volume dry as CH_4:	0.18	0.53	0.86	0.09	--
ppm @ 15% O_2 as CH_4:	0.21	0.60	0.97	0.10	--
lb/hr as CH_4:	0.56	1.614	2.543	0.265	2.9
lb/MMBtu as CH_4:	0.0003	0.0008	0.0012	0.0001	0.00132

Note: Results shown in italics are below the detection limit, and reported at the detection limit. Results for individual test runs are presented in Section 5.0.

TABLE 1-4
SUMMARY OF AVERAGE EMISSION TEST RESULTS SULFURIC ACID MIST, MAXIMUM LOAD MARSH LANDING GENERATING STATION JANUARY – APRIL 2013

Parameter	**CTG-1**	**CTG-2**	**Permit Limit**
Process Data:			
Fuel Flow, scf/hr:	1,976,407	1,963,670	
Gas turbine gross output, MW:	200.0	197.2	
Ammonia injection, lb/hr:	204.8	213.6	
Stack Gas Data:			
O_2, % volume dry	15.97	15.83	
Moisture content, % by volume	6.56	6.84	
Stack flow rate, dscfm	1,254,001	1,211,804	
Sulfur Dioxide (SO_2):			
ppm volume dry as SO_2	*0.044*	*0.046*	
lb/hr as SO_2	*0.55*	*0.56*	
lb/MMBtu as SO_2	*0.00027*	*0.00028*	
Sulfuric Acid / SO_3:			
ppm volume dry as SO_3	*0.083*	*0.088*	
lb/hr as H_2SO_4	*1.58*	*1.63*	
lb/MMBtu as H_2SO_4	*0.00077*	*0.00080*	
Entire Plant Sulfuric Acid, tons/year as H_2SO_4	5.41	*5.58*	7

Note: - Results in italics were below the detection limit.

Sulfuric acid mist (SAM) and SO_3 are counted together as liquid and gaseous phases of the same compound. The measurement was made by controlled condensation sampling train (EPA CTM-013). Entire plant tons/ year results are based on the maximum permitted heat input to the facility of 13,994,976 MMBtu/year per Condition 14 of the ATC.

TABLE 1-5
SUMMARY OF STARTUP EMISSION TEST RESULTS
MARSH LANDING GENERATING STATION
JANUARY – APRIL 2013

Run Number	Average CTG-1	Average CTG-2	Average CTG-3	Average CTG-4	Permit Limit
Startup Sequence Duration, min.	12.7	17.7	9.7	9.7	30
Total lb emitted per startup					
CO	12.5	34.2	16.2	5.4	216.2
NO_X as NO_2	8.6	9.6	4.7	3.6	36.4
Non-methane non-ethane HC	10.6	8.4	6.6	6.9	11.9

Note: These results were calculated from the data from one-minute intervals during each test run. See Section 5.0 for details of each test run.

TABLE 1-6
SUMMARY OF SHUTDOWN EMISSION TEST RESULTS
MARSH LANDING GENERATING STATION
JANUARY – APRIL 2013

Run Number	**Average CTG-1**	**Average CTG-2**	**Average CTG-3**	**Average CTG-4**	**Permit Limit**
Shutdown Sequence Duration, min.	6.0	11.0	5.3	5.3	15
Total lb emitted per shutdown					
CO	7.1	12.0	6.1	3.9	111.5
NO_X as NO_2	1.7	3.5	2.9	1.7	15.1
Non-methane non-ethane HC	2.8	4.4	2.7	4.5	5.4

Note: These results were calculated from the data from one-minute intervals during each test run. See Section 5.0 for details of each test run.

TABLE 1-7
SUMMARY OF AVERAGE EMISSION TEST RESULTS
FORMALDEHYDE EMISSIONS
MINIMUM AND MAXIMUM LOAD
MARSH LANDING GENERATING STATION
JANUARY – APRIL 2013

Parameter	**Average CTG-2 Minimum Load**	**Average CTG-2 Maximum Load**	**Permit Limit**
Process Data:			
Fuel Flow, scf/hr:	1,375,867	2,035,320	--
Gas turbine gross output,	124	179	--
Ammonia injection, lb/hr:	197.9	227.1	--
Stack Gas Data:			
O_2, % volume dry:	16.23	15.81	--
CO_2, % volume dry:	2.683	2.932	--
Stack Flow Rate, dscfm:	913,659	1,240,828	--
Formaldehyde Emissions:			
ppb vol. dry:	< 9.28	< 13.20	--
lb/hr:	< 0.040	< 0.076	--
lb/MMBTU:	< 2.84E-05	< 3.64E-05	--
lb/year, entire plant:	< 397	< 496	7,785

Note The formaldehyde results were calculated from the blank-corrected concentrations, but the non-blank corrected and CARB reporting limit emissions can be found in Appendix D. Results with "<" were below the limit of detection in at least one sample or sample fraction, but not in all samples or sample fractions. The lb/year results are based on the maximum permitted heat input to the facility of 13,994,976 MMBtu/year. Some process data were not available for this report.

TABLE 1-8
SUMMARY OF EMISSION TEST RESULTS
POLYCYCLIC AROMATIC HYDROCARBONS
MARSH LANDING GENERATING STATION
CTG-2 MINIMUM LOAD
JANUARY – APRIL 2013

Parameter		**Average, CTG-2**	
Process Data:			
Fuel Flow, scf/hr:		1,375,867	
Gas turbine gross output, MW:		124	
Ammonia injection, lb/hr:		197.9	
Stack Gas Data			
O_2, % volume dry		16.22	
CO_2, % volume dry		2.683	
Stack flow rate, dscfm		913,659	
PAH Emissions:	**ng/dscm**	**lb/hr**	**lb/MMBtu**
Benz(a)anthracene	ND< 2.240	ND< 7.66E-06	ND< 5.40E-09
Benzo(b)fluoranthene	ND< 2.240	ND< 7.66E-06	ND< 5.40E-09
Benzo(k)fluoranthene	ND< 2.240	ND< 7.66E-06	ND< 5.40E-09
Benzo(a)pyrene	ND< 2.240	ND< 7.66E-06	ND< 5.40E-09
Indeno(1,2,3-cd)pyrene	ND< 2.240	ND< 7.66E-06	ND< 5.40E-09
Dibenzo(a,h)anthracene	ND< 2.240	ND< 7.66E-06	ND< 5.40E-09
Total Specified PAH	ND< 13.44	ND< 4.60E-05	ND< 3.24E-08
Entire Plant, 13,994,976 Btu/year,		**Result**	**Permit Limit**
Total Specified PAH lb/year	--	ND< 0.45	1.98

Note: Results with a "ND<" denote that a species was not detected in sample and is reported at the detection limit. Results with "<" were below the limit of detection in at least one sample or sample fraction, but not in all samples or sample fractions. The detection limit value was used for all species below the limit of detection.

TABLE 1-9
SUMMARY OF EMISSION TEST RESULTS POLYCYCLIC AROMATIC HYDROCARBONS MARSH LANDING GENERATING STATION CTG-2 MAXIMUM LOAD JANUARY – APRIL 2013

Parameter		**Average, CTG-2**	
Process Data:			
Fuel Flow, scf/hr:		2,035,320	
Gas turbine gross output, MW:		179	
Ammonia injection, lb/hr:		227.1	
Stack Gas Data			
O_2, % volume dry		15.81	
CO_2, % volume dry		2.932	
Stack flow rate, dscfm		1,240,828	
PAH Emissions:	**ng/dscm**	**lb/hr**	**lb/MMBtu**
Benz(a)anthracene	ND< 2.368	ND< 1.10E-05	ND< 5.24E-09
Benzo(b)fluoranthene	ND< 2.368	ND< 1.10E-05	ND< 5.24E-09
Benzo(k)fluoranthene	ND< 2.368	ND< 1.10E-05	ND< 5.24E-09
Benzo(a)pyrene	ND< 2.368	ND< 1.10E-05	ND< 5.24E-09
Indeno(1,2,3-cd)pyrene	ND< 2.368	ND< 1.10E-05	ND< 5.24E-09
Dibenzo(a,h)anthracene	ND< 2.368	ND< 1.10E-05	ND< 5.24E-09
Total Specified PAH	ND< 14.21	ND< 6.47E-05	ND< 3.15E-08
Entire Plant, 13,994,976 Btu/year,		**Result**	**Permit Limit**
Total Specified PAH lb/year	--	ND< 0.44	1.98

Note: Results with a "ND<" denote that a species was not detected in sample and is reported at the detection limit. Results with "<" were below the limit of detection in at least one sample or sample fraction, but not in all samples or sample fractions. The detection limit value was used for all species below the limit of detection.

TABLE 1-10
SUMMARY OF BENZENE EMISSION TEST RESULTS
MARSH LANDING GENERATING STATION
MINIMUM AND MAXIMUM LOAD
JANUARY – APRIL 2013

Parameter	Average CTG-2 Minimum Load	Average CTG-2 Maximum Load	Permit Limit
Process Data:			
Fuel Flow, scf/hr:	1,375,867	2,035,320	--
Gas turbine gross output,	124	179	--
Ammonia injection, lb/hr:	197.9	227.1	--
Stack Gas Data:			
O_2, % volume dry:	16.24	15.81	--
CO_2, % volume dry:	2.683	2.932	--
Stack Flow Rate, dscfm:	913,659	1,240,828	--
Benzene Emissions:			
ppb vol. dry:	ND< 0.97	ND< 0.88	--
lb/hr:	ND< 0.012	ND< 0.013	--
lb/MMBTU:	ND< 7.62E-06	ND< 6.59E-06	--
lb/year, entire plant:	ND< 106.7	ND< 92.3	202

Note: Results with a ND< denote that the compound was not detected in sample and is reported at the detection limit. The lb/year results for Maximum Load are based on the maximum permitted heat input to the facility of 13,994,976 MMBtu/year.

SECTION 2.0

TESTING CONTRACTOR

Avogadro is a recognized independent contractor that has been approved to conduct emission source testing on behalf of the California Air Resources Board (CARB), pursuant to Section 91200-21220, Title 17, of the California Code of Regulations. Avogadro is accredited (interim) to ASTM Standard D-7036 as an air emission testing body (AETB) by the Source Test Accreditation Council (STAC). Avogadro is a full service source testing and emission test consulting firm with extensive experience in air quality management and pollution control.

Avogadro provided a professional source test team to conduct the testing as described in this report. Mr. Ian DeVivi, QSTI was project manager for the test program at the Marsh Landing facility in Antioch, California. As project manager, Mr. DeVivi's responsibilities included overseeing the execution of all air sampling efforts including management of the test team and reporting of the results. He was assisted in his efforts by Technical Director Kevin Crosby, QSTI and by a team including Project Managers Chris Crowley, QSTI, Kris Huckabay, QSTI and Todd Smith, QSTI. The primary objective of the project management was to ensure that the results generated by this testing program meet the expectations and requirements of Marsh Landing Generating Station, the CEC and the BAAQMD.

The tests were supervised by Qualified Individuals and met the quality standards of ASTM Standard D-7036.

SECTION 3.0

SOURCE LOCATION INFORMATION

3.1 FACILITY DESCRIPTION

The Marsh Landing Generating Station is located at 3201-C Wilbur Avenue in Antioch, California. The facility includes four Siemens STG6-5000F simple-cycle gas turbine engines. Each gas turbine has a rated maximum heat input of 2,202 MMBtu/hr. Each unit operates in simple-cycle mode and is equipped with a selective catalytic reduction (SCR) system and an oxidation catalyst for emissions control.

Each gas turbine unit includes a dry extractive continuous emission monitoring system (CEMS) for monitoring of O_2, CO and NO_X concentrations at the stack of each unit. The CEMS also includes monitoring of the fuel heat input to each unit, which is used in calculation of the mass emission rates of the pollutants. Each CEMS is therefore also a continuous emission rate monitoring system (CERMS).

3.2 SAMPLING LOCATIONS

Gas Turbine – Simple-Cycle Units: Samples were collected at the gas turbine exhaust stacks, from sampling ports that meet EPA and CARB Method 1 criteria. Each identical exhaust is a vertical, cylindrical stack, 165 feet tall and 31.33 feet inside diameter, with port access provided by stairways and ladders to a permanent platform that is 144 feet above the ground. There are four usable 6-inch NPT flange-style sampling port couplings with caps, located 90° apart from one another and installed 59 feet (1.9 stack diameters) downstream from (above) the nearest flow disturbance (the in-stack silencers) and 16 feet (0.5 diameters) upstream from (below) the stack exit.

The sampling port location was less than 2 stack diameters downstream from the stack's internal silencers. Therefore, the sampling location was evaluated as described in EPA Method 1, Section 11.4. The average yaw angle of the flow was within the criteria for an acceptable sampling location.

Note that these are large-diameter stacks with high-temperature stack gas (~750^{o}F). Special consideration was given to proper application and performance of the reference test methods to assure the quality of the data. A copy of a stack drawing is included in Appendix C.

At each gas turbine stack, 12 sampling traverse points were located according to EPA Method 1 (three points in each of four sampling ports) for the gaseous emission stratification checks. 24 sampling traverse points were located according to EPA Method 1 (6 points in each of four sampling ports) for the Particulate and PAH tests.

SECTION 4.0

TEST DESCRIPTION

4.1 PROGRAM OBJECTIVES

The testing program was conducted to meet the source testing requirements of the Authority to Construct permit issued by the BAAQMD, and the similar conditions of the permit from the CEC. The permit conditions that require testing are listed below.

Condition 10 – *"Within 90 days after startup of each turbine, the Owner/Operator shall conduct District and CEC approved source tests for that turbine to determine compliance with the emission limitations specified in Part 17. The source tests shall determine* NO_X*, CO, and POC emissions during* ***start-up and shutdown*** *of the gas turbines. The POC emissions shall be analyzed for methane and ethane to account for the presence of unburned natural gas. The source test shall include a minimum of* ***three start-up and three shutdown periods****. Thirty working days before the execution of the source tests, the owner/operator shall submit to the District and the CEC Compliance Program Manager (CPM) a detailed source test plan designed to satisfy the requirements of this Part. The District and the CEC CPM will notify the owner/operator of any necessary modifications to the plan within 20 working days of receipt of the plan; otherwise, the plan shall be deemed approved. The owner/operator shall incorporate the District and the CEC CPM comments into the test plan. The owner/operator shall notify the District and the CEC CPM within seven (7) working days prior to the planned source testing date. The owner/operator shall submit the source test results to the District and the CEC CPM within 60 days of the source testing date."*

The tests for this condition therefore included:

- NO_X, CO, POC, ppmvd, lb/hr during start-up and shutdown

Condition 27 – *"Within 90 days of start-up of each of the MGLS SGT6-5000F units, the owner/operator shall conduct a District-approved source test on the exhaust point* ***P-1, P-2, P-3, or P-4*** *to determine the corrected ammonia* (NH_3) *emission concentration to determine compliance with Part 17(e). The source test shall* ***determine the correlation*** *between the heat input rates of the gas turbine, A-2, A-4, A-6, or A-8 SCR system ammonia injection rate, and the corresponding* NH_3 *emission concentration at emission point P-1, P-2, P-3, or P-4. The source test shall be conducted over the expected operating range of the turbine (including, but not limited to,* ***minimum and full load*** *modes) to establish the range of ammonia injection rates necessary to achieve* NO_X *emission reductions while maintaining ammonia slip levels. The owner/operator shall repeat the source testing on an annual basis thereafter. Ongoing compliance with Part 17 (e) shall be demonstrated through calculations of corrected ammonia concentrations* *based upon the source test correlation and continuous records of ammonia injection rate. The owner/operator shall submit the source test results to the District and the CEC CPM within 60- days of conducting the tests."*

The tests for this condition therefore included:

- NH_3, ppmvd, ppmvd @ 15% O_2 on all units at minimum and full load

Condition 28 – *"Within 90 days of start-up of each of the MGLS SGT6-5000F units and on an annual basis thereafter, the owner/operator shall conduct a District-approved source test on each corresponding exhaust point* ***P-1, P-2, P-3, and P-4*** *while each Gas Turbine is operating at* ***maximum load*** *to determine compliance with Parts 17(a), 17 (b), 17(c), 17(d), 17(f), 17(g), 17(h), 17(i) and while each Gas Turbine is operating at* ***minimum load*** *to determine compliance with Parts 17c, and 17(d) and to verify the accuracy of the continuous emissions monitors required in Part 24. The owner/operator shall test for (as a minimum): water content, stack gas flow rate, oxygen concentration, precursor organic compound concentration and mass emissions, nitrogen oxide concentration and mass emissions (as* NO_2*), carbon monoxide concentrations and mass emissions, sulfur dioxide concentration and mass emissions, methane, ethane, and total particulate matter emissions including condensable particulate matter. The owner/operator shall submit the source test results to the District and the CEC CPM within 60 days of conducting the tests."*

The tests for this condition therefore included:

- Maximum load on each turbine
    - Moisture content, %
    - Flow rate, dscfm
    - O_2, %
    - PM_{10}, gr/dscf, lb/hr and lb/MMscf
    - NO_X, CO, POC, methane, ethane, ppmvd and lb/hr
    - SO_2, ppmvd, lb/hr and lb/MMscf (from fuel)
    - Relative Accuracy Test Audit (RATA) of the CEMS and CERMS

- Minimum load on each turbine
    - CO, ppmvd, lb/hr

Condition 30 – *"Within 90 days of start-up of each of the MGLS SGT6-5000F units and on an biennial basis (once every two years) thereafter, the owner/operator shall conduct a District-approved* ***source test on one*** *of the following exhaust points* ***P-1, P-2, P-3, or P-4*** *while the Gas Turbine is operating at* ***maximum allowable operating rates*** *to demonstrate compliance with Part 23. The owner/operator shall also test the gas turbine while it is operating at* ***minimum load****. If three consecutive biennial source tests demonstrate that the annual emission rates calculated pursuant to Part 26 for any of the compounds listed below are less than the BAAQMD trigger levels, pursuant to the*

Regulation2, Rule 5, show, then the owner/operator may discontinue future testing for that pollutant:

> *Benzene $\leq$ 3.8 pounds/year and 2.9 pounds/hour*
> *Formaldehyde < 18 pounds/year and 0.12 pounds/hour*
> *Specified PAHs $\leq$ 0.0069 pounds/year"*

The tests for this condition therefore included:

- Maximum load and minimum load on one turbine
    - Benzene, ppmvd, lb/hr, lb/MMBtu
    - Formaldehyde, ppmvd, lb/hr, lb/MMBtu
    - PAH, ppmvd, lb/hr, lb/MMBtu

Condition 32 – *"Within 90 days of start-up of each of the first two MGLS SGT6-5000F units and on an annual basis thereafter, the owner/operator shall conduct a District-approved source test on* ***two of the four*** *exhaust points P-1, P-2, P-3, and P-4 while each Gas Turbine is operating at* ***maximum heat input*** *rates to demonstrate compliance with SAM emission rates specified in Part 33. The owner/operator shall test for (as a minimum) SO_2, SO_3, and H_2SO_4. The owner/operator shall submit the source test results to the District and the CEC CPM within 60 days of conducting the tests."*

The tests for this condition therefore included:

- Maximum load on two turbines
    - SO_2, SO_3, and H_2SO_4, ppmvd, lb/hr

This report presents the results of the emission tests in comparison to the applicable permit limits. The results are presented in units consistent with those listed in the permit, as summarized in Table 4-1.

TABLE 4-1
PERMIT EMISSION LIMITS
MARSH LANDING GENERATING STATION

Parameter	Units	Permit Limit	Permit Condition
Each Gas Turbine			
Nitrogen Oxides	ppmvd @ 15% O_2	2.5 (1hr avg)	17b
	lb/hr	20.83	17a
	lb/MMbtu	0.00946	17a
	lb/startup	36.4	18
	lb/shutdown	15.1	18
	lb/hr containing a startup	45.1	18
Carbon Monoxide	ppmvd @ 15% O_2	2.0 (1 hr avg)	17d
	lb/hr	10.0	17c
	lb/MMbtu	0.00454	17c
	lb/startup	216.2	18
	lb/shutdown	111.5	18
	lb/hr containing a startup	541.3	18
Precursor Organic Compounds	lb/hr	2.9	17f
	lb/MMbtu	0.00132	17f
	lb/startup	11.9	18
	lb/shutdown	5.4	18
	lb/hr containing a startup	28.5	18
Particulate Matter	PM_{10}, lb/hr	9.0	17h
	Total PM, lb/hr	9.0	17i
Sulfur Oxides	lb/hr	6.21	17g
	lb/MMbtu	0.0028	17g
Ammonia	ppmvd @ 15% O_2	10.0 (3hr rolling avg)	17e
Sulfuric Acid Mist (SAM)	Entire plant, tons/12 months	7	33
Formaldehyde	Entire plant, lb/yr	7,785	23
Benzene	Entire plant, lb/yr	202	23
PAH specified	Entire plant, lb/yr	1.98	23

Note: See the permit document for complete details of these permit conditions.

4.2 TEST CONDITIONS

The permit conditions require testing of each gas turbine at two steady-state load conditions:

- Minimum gas turbine load (Min load). This load condition is defined as the minimum load at which each turbine will operate in a stable manner with NO_X and CO emissions within permit limits. The plant CEMS was used to determine the NO_X and CO emissions for this determination.
- Maximum gas turbine load. Some permit conditions call for testing at the "maximum load" or the "maximum allowable operating rates" and some at the "maximum heat input rates." These descriptions will be regarded as equivalent to a condition at or near the highest load rate attainable at the ambient conditions present at the time of the test. Since the plant chiller system will maintain the inlet temperature at 46^{o}F at 100% base load, the turbine output will not vary significantly.

The federal regulations (40CFR60, Subpart KKKK) require testing of each gas turbine at a load within 25% of peak load. These test requirements were covered by the testing program at the maximum load condition.

Test conditions were established on site by plant personnel. Since the ambient air density conditions affect operation of a gas turbine, the actual megawatts generated at any load condition or fuel heat input rate varied somewhat.

Process data was provided by the plant operation staff to Avogadro including the parameters listed below.

For each gas turbine unit:

- Gross MW produced
- Fuel flow rate or fuel heat input to the gas turbine
- Ammonia injection rate
- CEMS output data

4.3 TEST PROGRAM SCHEDULE

The test program was planned to be completed in two mobilizations, but process availability changed the plan so that several mobilizations were necessary to complete the test program. The order of some of the tests was changed so that certain tests could be completed within permit deadlines. The actual schedule is presented in Table 4-2.

TABLE 4-2
REVISED TEST SCHEDULE
MARSH LANDING GENERATING STATION

DAY, 2013	LOCATION/ACTIVITY	TEST RUNS	RUN TIME
Jan. 25	**Mobilization 1**, safety briefing, set-up	**--**	**--**
Jan. 28	**Unit 1 Min Load -** CO, NH_3 Startup NO_X, CO, POC Shutdown NO_X, CO, POC	#1, 2, 3 #1 of 3 #1, 2 of 3	30 min. each ~50 min. ~30 min. ea.
Jan. 29	**Unit 1 Full Load** – PM, SAM POC, NH_3 NO_X, CO, O_2 (RATA for Cemtek) Fuel sample for SO_X	#1, 2 of 3 #1, 2 of 3 #1 to 9 or more 1	240 min. ea. 30 min. each 21 min. each grab
Jan. 30	**Unit 1 Full Load** – PM, SAM POC, NH_3**,** NO_X Startup NO_X, CO, POC Shutdown NO_X, CO, POC	#3 of 3 #3 of 3 #2, 3 of 3 #3 of 3	240 minutes 30 minutes ~50 min. ea. ~30 min. ea.
Feb. 1	***Equipment Recovery***	--	--
Feb. 25	**Mobilization 2**, set-up **Unit 2**	**--**	**--**
Feb 26	**Unit 2 Min Load -** CO, NH_3, Benzene PAH, Formaldehyde	#1 of 3 #1 of 3	30 minutes 240 minutes
Feb. 27	**Unit 2 Min Load -** CO, NH_3, Benzene PAH, Formaldehyde	#2, 3 of 3 #2, 3 of 3	30 min. each 240 min. ea.
Feb. 28	**Unit 2 Full Load -** CO, NH_3, Benzene PM, PAH, Formaldehyde	#1 of 3 #1 of 3	30 minutes 240 minutes
Mar. 6	**Unit 2 Full Load** – PM, PAH, Formaldehyde POC, NH_3, Benzene NO_X, CO, O_2 (RATA for Cemtek)	#2, 3 of 3 #2, 3 of 3 #1 to 9 or more	240 min. ea. 30 min. each 21 min. each
Mar. 12	***Unit 1 Full Load*** *– SAM Re-Test* **Unit 2 Full Load -** SAM	*#1, 2 of 3* #1, 2 of 3	*240 min. ea.* 240 min. ea.
Mar. 13	***Unit 1 Full Load*** *– SAM Re-Test* **Unit 2 Full Load** – SAM **Unit 2** Startup, Shutdown NO_X, CO, POC Fuel sample for SO_X	*#3 of 3* #3 of 3 #1, 2, 3 each 1	*240 minutes* 240 minutes ~20 min. ea. grab
Mar. 14	***Equipment Recovery***	--	--

Note: This schedule was changed from the original plan to meet process availability, and to complete some of the tests within the deadlines imposed by permit conditions. The Unit 1 Sulfuric Acid Mist tests were repeated on March 12-13 because the first test set was not representative due to contaminated glassware.

TABLE 4-2 (continued)
REVISED TEST SCHEDULE
MARSH LANDING GENERATING STATION

DAY, 2013	LOCATION/ACTIVITY	TEST RUNS	RUN TIME
Mar. 18	**Mobilization 3**, set-up **Unit 3**	**--**	**--**
Mar. 19	**Unit 3 Full Load –** PM	#1 of 3	240 minutes
--	**--**	--	--
Mar. 26	**Unit 3 Min Load -** CO, NH$_3$	#1, 2 of 3	30 min. ea.
Mar. 27	**Unit 3 Min Load -** CO, NH$_3$ **Unit 3 Full Load –** PM	#3 of 3 #2, 3 of 3	30 minutes 240 min. ea.
--	--	--	--
Apr. 13	**Unit 3 Full Load –** POC, NH$_3$ NO$_X$, CO, O$_2$ (RATA for Cemtek)	#1 of 3 #1 to 5	30 minutes 21 min. ea.
Apr. 14	**Unit 3 Full Load –** POC, NH$_3$ NO$_X$, CO, O$_2$ (RATA for Cemtek) Fuel sample for SO$_X$	#2, 3 of 3 #6 to 10 1	30 min. ea. 21 min. ea. grab
Apr. 15	***Move to Unit 4***	--	--
Apr. 16	**Unit 4 Min Load -** CO, NH$_3$ **Unit 4 Full Load –** PM POC, NH$_3$ NO$_X$, CO, O$_2$ (RATA for Cemtek)	#1, 2, 3 #1 of 3 #1 of 3 #1, 2 of 10	30 min. ea. 240 min. ea. 30 minutes 21 min. ea.
Apr. 17	**Unit 4 Full Load –** PM POC, NH$_3$ NO$_X$, CO, O$_2$ (RATA for Cemtek)	#2, 3 of 3 #2, 3 of 3 #1 to 10	240 min. ea. 30 min. ea. 21 min. ea.
Apr. 19	**Unit 4 -** Fuel sample for SO$_X$	1	grab
Apr. 20	***Unit 1*** *Re-Test Startup NO$_X$, CO, POC* *Re-Test Shutdown NO$_X$, CO, POC* **Unit 4** Startup NO$_X$, CO, POC Shutdown NO$_X$, CO, POC	*#1, 2, 3* *#1, 2, 3* #1, 2, 3 #1, 2, 3	*~15 min. ea.* *~10 min. ea.* ~10 min. ea. ~5 min. ea.
Apr. 21	**Unit 3** Startup NO$_X$, CO, POC Shutdown NO$_X$, CO, POC	#1, 2, 3 #1, 2, 3	~10 min. ea. ~5 min. ea.
Apr. 22	***Recover Equipment***	--	--

Note: This schedule was changed from the original plan to meet process availability, and to complete some of the tests within the deadlines imposed by permit conditions. The Unit 1 Startup-Shutdown tests were repeated on April 20 because the first test set was conducted before the rapid startup and shutdown rate tuning had been completed.

4.4 TEST PROCEDURES

The test procedures used by Avogadro in this testing program are summarized in Table 4-3. Descriptions of standard procedures are included in Appendix A. Additional information on specific applications or modifications to standard procedures is presented in the following sub-sections. Where any conflicts exist in the descriptions, the specific descriptions here in Section 4.4 will take precedence.

TABLE 4-3
EMISSION TEST PARAMETERS AND METHODS MARSH LANDING GENERATING STATION

Test Parameter	Reference Method	Analytical Approach
O_2 and CO_2	EPA 3A	Paramagnetic and NDIR analyzers
NO_X	EPA 7E	Chemiluminescent analyzer
CO	EPA 10	NDIR/GFC analyzer
POC (with methane and ethane) *	EPA 18, EPA TO-12 (compliance)	GC-FID (methane and ethane), Pre-concentration and GC-FID
POC (with methane and ethane)	BAAQMD ST-7 with EPA 18 (startup-shutdown)	FID analyzer (total HC) Bag sampling, GC-FID (methane and ethane)
Total PM as PM_{10}	EPA 5 & 202	Filterable and condensable
Ammonia (NH_3)	BAAQMD ST-1B	Ion selective electrode
Sulfur Oxides (SO_X)	From fuel sulfur*	Calculation from fuel sulfur content*
Fuel Sulfur	ASTM D-5504	GC/MS/FPD
SO_2, SO_3, and H_2SO_4 (SAM)	EPA CTM-13	Controlled condensation, ion chromatography
Benzene	EPA TO-15	GC/MS
Formaldehyde	CARB 430	HPLC
PAH **	CARB 429	High Resolution GC/MS
Emission rates, lb/MMBtu, lb/hr	EPA 19	Calculated from fuel flow
Stack gas velocity	EPA 1 and 2	Pitot tube traverse
Moisture content	EPA 4	Moisture condensation, gravimetry

Note: Emissions of SO_2 were calculated from the fuel sulfur content and the fuel flow rate; this technique provided a conservatively high estimate of the emissions because it assumed that all the sulfur in the fuel is converted to SO_2.

* Modified EPA Method TO-12 was used as a sampling and analysis protocol for EPA Method 18 in order to achieve sufficiently low detection limits for this case.

** Certain PAH compounds were specified by BAAQMD for emission measurement.

4.4.1 Gaseous Emissions

Concentrations of the gaseous constituents of the stack gas (NO_X, CO, O_2 and CO_2) were measured using EPA Methods 7E, 10 and 3A. A preliminary 12-point stratification check was conducted for determination of the traverse point requirements for the subsequent test runs. If the measured concentrations were within 10% of the average concentration, then a three-point traverse was used for the subsequent test runs. If the measured concentrations were within 5% of the average concentration, then a single sampling point was used.

The tests were performed using Avogadro's dry extractive continuous emissions monitor (CEM) system described in Appendix A. This system meets the requirements of EPA and CARB methods for gaseous species. A heated Teflon line and chilled knockout system will be used to prevent loss of NO_2 in the sampling system. The NO_X analyzer was operated in the NO_X mode to measure NO plus NO_2. A converter was used to convert NO_2 to NO for measurement of total NO_X.

The sample conditioning and delivery system includes components to extract a representative sample from the source, remove the moisture and particulate matter from the sample stream, and transport the sample to the analyzers. The main components are:

1) A Teflon, titanium, stainless steel, quartz or glass probe - heated or insulated as necessary to avoid condensation,
2) Sample filtration – filters located on the probe, pump, and prior to all of the analyzers for removal of particulate matter,
3) Teflon tubing - connecting the probe to the sample conditioner and the sample conditioner to the analyzer manifold - heated or insulated as necessary to avoid condensation,
4) Sample conditioner - glass or stainless steel flasks immersed in an ice bath to remove the moisture from the sample gas stream,
5) Vacuum pump - a leak-free pump with Teflon diaphragm to transport the sample gas through the system,
6) Sample manifold - a distribution system, constructed of stainless steel and Teflon tubing, to direct sample gas to the analyzers, and
7) Sample flow rate control - a series of rotameters, vacuum gauges and pressure gauges connected to the manifold used to maintain the appropriate sample flow rates.

The calibration gas system utilizes only EPA Protocol gases to verify the operation, linearity, and range settings of the electronic analyzers. The sample gas system allows for the introduction of the protocol gases to the analyzers either directly through the manifold (calibration error check - performed once daily) or through the sampling system (system bias check - performed with each run).

The electronic analyzers are rack-mounted and are maintained in the mobile lab. The data recording and acquisition system is based on a digital system known as MoleDAQ. It includes software for controlling the collection of calibration and emission monitoring data, and hardware for connection of the analyzer outputs to the recording system.

Test results can be provided in three forms: On-site printouts of the digitized data, diskette recordings of the digitized data, and strip charts from the monitoring data. For this test program, the results have been provided as on-site printouts of the one-minute averages.

4.4.2 Relative Accuracy Test Audit and Bias Test

The relative accuracy test audit (RATA) and bias tests were conducted under a separate contract (to CEMTEK) and those results are presented in a separate report. However, the results of some of the RATA test runs were also used to determine compliance with the permit conditions. The description of the RATA and bias tests and calculations can be found in that separate report.

4.4.3 Precursor Organic Compounds and Benzene (steady-state conditions)

The concentrations of precursor organic compounds (POC) were measured using EPA Method 18. The emission limit for POC is equivalent to approximately 2 ppm volume dry, which requires lower detection limits than are typical with the standard approaches to Method 18. The sampling and analysis techniques of EPA Compendium Method TO-12 were therefore used as a protocol for Method 18 in order to provide low enough detection limits to prove compliance.

Stack gas samples were collected in specially-prepared evacuated stainless-steel (SUMMA) canisters. Sample gas was drawn through a probe and connecting line of Teflon tubing through a calibrated flow controller into each canister. The sample flow rate was controlled so that a partial vacuum (i.e. at least 5 inches Hg) remained in the canister to prevent condensation within the sample.

Triplicate 30-minute sampling runs were conducted on each unit as specified in Table 3-2. Each test run was performed at a flow rate of approximately 0.1 liters per minute at one atmosphere. After sample collection, the canister was transported to the laboratory for cryogenic pre-concentration and flame ionization detection analysis as described in Method TO-12 within 14 calendar days. The expected detection limit for this technique is on the order of 10 ppb by volume.

Results have been reported by the laboratory as concentrations of non-methane non-ethane organic compounds as methane or heptane (converted to the basis "as methane"). The canisters were prepared and analyzed by Air Toxics, Ltd. of Folsom, California.

The canister contents were also analyzed for the content of methane and ethane by gas chromatography. This was done to satisfy the permit condition; the results were not needed for calculation of the test results for POC. The analytical results for methane and ethane are presented in Appendix E.3.

The sample contained in the canister was also analyzed for the concentration of benzene (from one gas turbine unit). The analysis was conducted by gas chromatography – mass spectroscopy using EPA Method TO-15. This method provides a positive identification of the benzene "peak" and accurate quantification with a detection limit of approximately 0.5 ppb volume dry.

4.4.4 Precursor Organic Compounds (startup and shutdown sequences)

Startup is defined in the permits as "the lesser of the first 30 minutes of continuous fuel flow to the turbine after fuel flow is initiated or the period of time from gas turbine fuel flow initiation until the gas turbine achieves two consecutive CEM data points in compliance with the emissions concentration limits of conditions 17(b) and 17(d)" of the permit.

Shutdown is defined in the permits as "the lesser of the 15-minute period immediately prior to the termination of fuel flow to the gas turbine or the period of time from non-compliance with any requirement listed in Conditions 17(a) through 17(d) until termination of fuel flow to the gas turbine."

A gaseous emissions test run (CO, NO_X and POC) was performed on each unit during each of three startup and shutdown sequences. The POC tests consisted of operating a FID analyzer according to BAAQMD Method ST-7 (to monitor concentrations of total hydrocarbons) in conjunction with the collection of Tedlar bag samples as described below. The bag samples were then analyzed in the Avogadro laboratory by GC/FID according to EPA Method 18. The results from the bag samples were used to determine the non-methane non-ethane hydrocarbon fraction of the total hydrocarbon results provided by the one-minute average data from the ST-7 test run. The test runs were approximately 15 minutes in duration during each startup period and approximately 10 minutes in duration during each shutdown period.

A series of bag samples was taken during each run to provide average concentrations for each time interval during the run. The length of each interval was determined prior to the test, as Avogadro and the unit operators reviewed the typical timing of the startup and shutdown fuel flow and load ramping sequences. Intervals were 2 to 10 minutes in length during the various phases of the startup or shutdown (i.e. concentrations change faster or more slowly during different parts of the sequence) in order to properly characterize the non-methane non-ethane hydrocarbon fraction of the total hydrocarbon results.

4.4.5 Particulate Matter less than 10 µm (PM_{10})

The concentrations and emission rates of PM_{10} were characterized by measuring total particulate matter (PM) and assuming that all of it is PM_{10}. The emissions were measured using a combination of EPA Methods 5 and 202. The measurements therefore included filterable and condensable particulate matter (CPM). The Method 5 "front-half" or "filterable PM_{10}" samples were handled as described in the Method. The EPA Method 202 "back-half" or "condensable PM_{10}" samples were handled as described in that method as promulgated in December 2010.

Traverse points were determined according to EPA Method 1. Each test run at the gas turbine units was 168 minutes in duration in order to collect sufficient sample volume to provide detection limits low enough to determine compliance with the permit conditions.

The apparatus included a stainless-steel or glass sampling nozzle and a heated probe of borosilicate glass tubing, connected to a heated glass filter holder with a glass-fiber filter. The filter holder was mounted inside an oven box at the back end of the sampling probe, and was connected to the impinger train with a length of heated flexible Teflon tubing (the "probe extension"). The impinger train was connected to the control box, which contains the sampling pump and dry gas meter. The nozzle size was chosen to allow isokinetic sampling at all the traverse points.

The filterable "front-half" PM was recovered from the sampling apparatus as described in EPA Method 5. The two sample fractions included the filter and the combined rinses of the nozzle, the probe, and the front-half of the filter holder. The samples were analyzed gravimetrically to determine the mass of filterable PM.

The impinger train or "back-half" contents were recovered and analyzed for condensable PM as described in EPA Method 202. After sampling, a leak check was conducted from the probe tip through the impinger train. Then the probe extension and condenser were rinsed with a known amount of water into the first impinger or dropout (i.e. with the sampling pump running), the pump was turned off and the probe extension was disconnected from the impinger train. The probe extension was then rinsed with acetone and hexane into the organic rinse sample bottle (#2). The impinger train was capped and it and the organic rinse sample were transported to the mobile laboratory.

In the mobile laboratory, the first and second impingers were weighed to determine the mass of moisture collected. The contents of the first impinger were rinsed with water into the second impinger, and water was added as necessary for the subsequent purge. Then the condenser and first impinger were reattached to the second impinger and the condenser, impingers and CPM filter were purged with nitrogen for one hour.

After the purge, the sample was recovered in three fractions. These included **(#3)** the CPM filter, **(#1)** the water contents and rinses of the condenser, impingers, and filter holder, and **(#2)** the acetone and hexane rinses of the condenser, impingers, and filter holder. The sample containers were transported to the Avogadro laboratory for analysis. In the laboratory, the samples were processed and analyzed as described in Method 202. The analysis of the samples included gravimetric measurement of the residue from the filter, each front half acetone rinse, and the aqueous and organic fractions of CPM.

4.4.6 Ammonia

Concentrations of ammonia were determined using Bay Area AQMD Method ST-1B. Triplicate 30-minute test runs were performed on each gas turbine unit at each load condition as shown in Tables 4-1 and 4-2.

The sampling apparatus included a probe of glass or titanium tubing connected by a length of Teflon tubing to a series of impingers immersed in an ice bath. The first two impingers contained 0.1N hydrochloric acid solution, the third was empty and the fourth was charged with indicating silica gel. The probe tip was inserted into the stack to a point approximately one third of the stack diameter from the stack wall. Sample stack gas was drawn through the sampling apparatus with a leak-free pump, connected in series to a calibrated dry gas meter and flow-metering orifice. Sample gas was drawn at a rate of approximately 0.7 cfm for each test run.

The sample from the first two impingers was recovered into two sample containers. The sample in each container was analyzed using a calibrated ion selective electrode to determine the ammonia concentration.

4.4.7 Fuel Analysis and SO_2 emissions

One sample from each turbine's natural gas fuel supply pipeline was collected into a Tedlar bag during testing of that unit. The samples were submitted to the Eurofin Air Toxics laboratory in Folsom, CA for analysis within 48 hours of sampling. Samples from some of the units were collected into specially-lined high-pressure stainless steel cylinders. The sample cylinders were submitted to Texas OilTech Laboratories, Inc. in Houston, Texas for analysis within 10 days of sampling.

The analysis provided results of trace fuel sulfur compounds by ASTM Method D-5504. The results have been used with fuel flow rates in calculation of SO_2 emissions; the mass flow of fuel was converted into the mass flow rate of SO_2 by assuming that all the fuel sulfur was converted to SO_2. The stack gas concentration of SO_2 (in units of ppm volume dry) was back-calculated from the mass emission rate and the stack gas flow rate.

4.4.8 Sulfuric Acid Mist, Sulfur Trioxide and Sulfur Dioxide Emissions

Concentrations of sulfur compounds were measured using EPA Conditional Test Method (CTM) 013, also known as National Council for Air and Stream Improvement (NCASI) Method 8A or the “controlled condensation” method. The test runs provided results for emissions of sulfuric acid mist (H_2SO_4 or SAM) with sulfur trioxide (SO_3), and sulfur dioxide (SO_2). Note that SAM and SO_3 are collected together (as SAM is just condensed SO_3) and the results are reported as SAM. Therefore, the test results are reported as concentrations and mass emission rates of SAM and SO_2.

A diagram of the sampling train is provided in Figure 4-1. Note that the method includes operation of the sampling probe and filter at a temperature high enough for dissociation of ammonium sulfate (which occurs at 455^{o}F) into SO_3 so that it will pass through the filter to the condenser, and to maintain the condenser temperature low enough to condense at least 95% of the expected concentration of SO_3 but high enough to prevent condensation of water vapor.

The critical temperatures, based on the spreadsheet shown in the protocol in Appendix A, are shown in the table below:

Parameter	**Expected**	**Dew point ^{o}F**
SAM/SO_3	< 0.10 ppm	200
5% of expected	0.005 ppm	159
H_2O	8 % vol.	110
Planned Condenser Temp.	**155 ±10 ^{o}F**	--

Note: The acid dew point at 5% of the expected value is used to denote at least 95% collection at that temperature.

After sample collection, the system was leak-checked and then dissembled for sample recovery. The condensed SAM was recovered from the condenser coil and frit by rinsing with de-ionized water into Sample Container 1. The contents of Impingers 1 and 2 was recovered with de-ionized water into Sample Container 2. The contents of each container were analyzed using the barium-thorin titration method (or ion chromatography for lower detection limits) and the results have been used to calculate stack gas concentrations of the combination of SAM and SO_3, and SO_2.

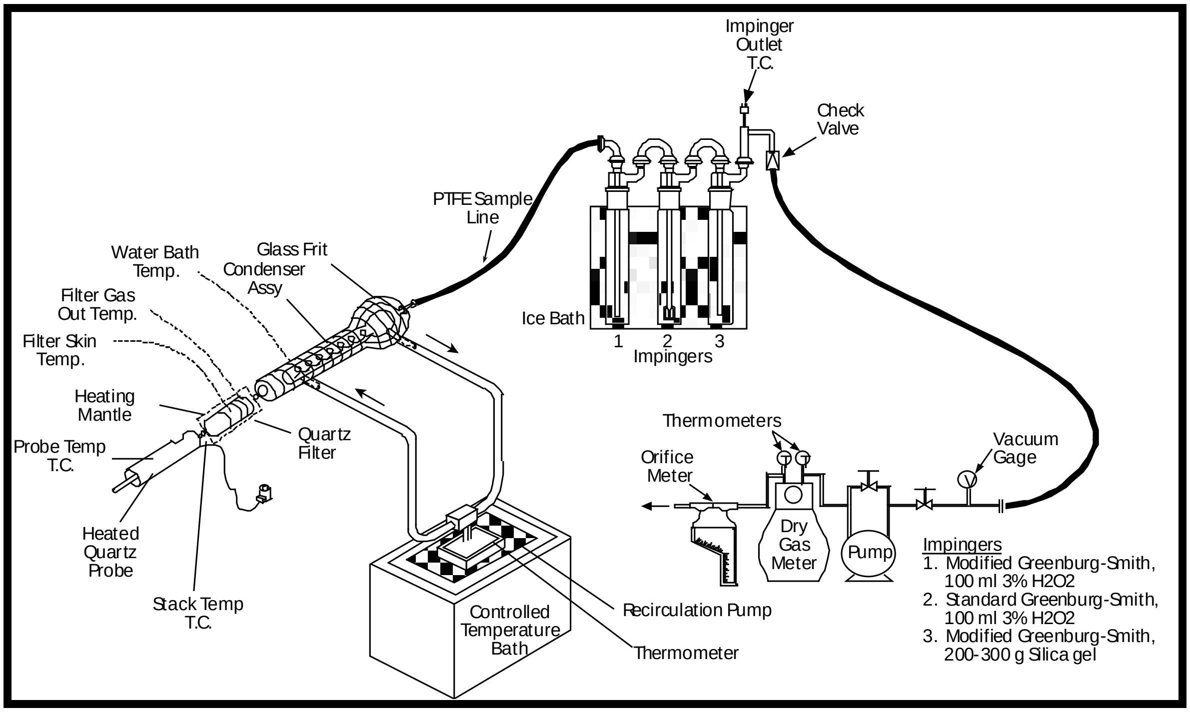

Figure 4-1. Controlled condensation with EPA Method 6/8 sampling train.

4.4.9 Formaldehyde Emissions

Measurements of formaldehyde concentrations were made by CARB Method 430. Three 4-hour sampling runs were conducted in order to measure the target concentration. The planned sample volume and sampling time were calculated by pre-test planning calculations as described in the Method. Three field blank samples were taken as described in the Method.

The DNPH sampling solution was prepared and analyzed by the AA&C laboratory in Ventura, California. AA&C shipped the DNPH solution to Avogadro for use in the field. Each sampling was started within 48 hours of the last blank reagent analysis. Avogadro (or Delta for the full-load test runs) collected and recovered the samples, protected them from contamination, and shipped them to AA&C for analysis.

The results have been presented in terms of blank-corrected or non-corrected concentrations, depending on the sample-to-blank concentration ratio. Results have also been calculated and reported in comparison to the reporting limit as calculated using CARB Method 430. Complete documentation of the calculations can be found in Appendix D.7.

4.4.10 Polycyclic Aromatic Hydrocarbon Emissions

Method: CARB 429, Amended July 28, 1997
Deviations: There are no planned deviations from the method

Tester:	The Avogadro Group, LLC
Contact:	Ian DeVivi (925) 429-9020, fax (925) 680-4416
Lab:	Vista Analytical Laboratory, El Dorado Hills, California
Contact:	Martha Maier (916) 933-1640, fax (916) 933-0940
Analysis:	High-resolution capillary column gas chromatography with high-resolution mass spectrometry (HRGC/HRMS).

Test Description: Measurements of the emissions of polycyclic aromatic hydrocarbon (PAH) compounds was performed according to the procedures of CARB Method 429. The six target analytes specified by the BAAQMD are:

PAHs:
benzo(a)anthracene
benzo(b)fluoranthene
benzo(k)fluoranthene
benzo(a)pyrene
dibenzo(a,h)anthracene
indeno(1,2,3-cd)pyrene

Each of the triplicate test runs was 240 minutes in duration and the sampling was performed isokinetically with a multi-point traverse of the sampling plane. The total sample volume for each run was approximately 125 dscf.

One field blank at each test condition was prepared, recovered and analyzed according to the method. Reagent blanks were also collected; however, these samples were not analyzed, as there were no anomalies in the field blank analysis.

Pre-test Cleaning Procedure: All glassware and Teflon sampling apparatus being exposed to the sample (this includes the probe nozzle, probe liner, filter assembly, Teflon connecting tube, condenser, resin cartridge and impingers) was cleaned prior to use per the following procedures:

a Soak in a hot solution of Liquinox detergent and water;
b Following soaking, rinse six times with hot tap water;
c Next, soak in chromic acid cleaning solution for at least four hours;
d Next, rinse three times with DI water;
e Next, rinse with acetone, hexane, and methylene chloride;
f Next, dry in a 200 °F oven;

All the cleaned glassware and Teflon parts was sealed in methylene chloride-rinsed aluminum foil. Sampling reagents included pre-cleaned glass fiber filters and XAD resin cartridges charged with pre-cleaned Amberlite XAD-2 resin. The filters and resin cartridges were pre-cleaned and screened for contamination by Vista Analytical Laboratory. Pesticide-grade (Fisher Scientific *Optima* grade or equivalent) acetone, hexane and methylene chloride reagents were used as recovery solvents.

Sample Train Operation: Pretest preparations, preliminary determinations, and leak check procedures were those outlined in EPA Method 5 and CARB 429. Borosilicate glass probe liners and nozzles were used to avoid possible contamination and sealing greases were not used on the sample train.

The sampling train was operated in the same manner as a regular EPA Method 5 sampling train. The sampling apparatus included a heated glass probe equipped with an S-type pitot tube and thermocouple. The probe was attached to an oven containing a heated filter holder, Teflon frit and pre-cleaned glass-fiber filter. Both the probe exit temperature and oven were maintained at 248°F ± 25°F during sampling. We did not use the optional cyclone pre-separator since the grain loading of the flue gas was relatively low. The filter holder was connected by a length of flexible Teflon tubing to a condenser coil and XAD-2 sorbent trap. The temperature of the gas entering the sorbent trap was maintained below 68 °F at all times. The trap was connected directly to the impinger train containing four chilled impingers in series. The impinger train was connected to the control box containing the sampling pump and calibrated dry gas meter.

The first and second impingers each contained 100 ml of a sodium carbonate / bicarbonate solution, the third was empty, and the fourth impinger contained silica gel. The entire sample train was leak tested once prior to sampling and once following testing. The pre-test leak check was performed at a nominal vacuum to ensure that leakage did not exceed 0.02 cfm. The post-test leak check was performed at a vacuum greater than the highest vacuum recorded during the test to ensure that leakage did not exceed the lesser of a) 4 percent of the average sampling rate, or b) 0.02 cfm. The sampling rate and nozzle size were chosen to allow isokinetic sampling.

Sample Recovery: Avogadro (or Delta) collected and recovered the samples, protected them from contamination, and delivered them to the laboratory for analysis within the method’s hold time. Exposed glassware openings in the sampling train were covered with hexane-rinsed foil, to avoid contamination, immediately following the final leak check. All the method’s QA/QC and chain of custody procedures were strictly followed.

All sample fractions, except the resin cartridges, were collected in methylene chloride-rinsed amber glass jars with Teflon-lined lids. The liquid level (if applicable) was marked on each sample container. The contents of the impingers was weighed and recorded prior to recovery.

The nozzle, probe and front-half of the filter holder were all rinsed into Container 1 using measured volumes of acetone, hexane, and methylene chloride (three times each in that order). The filter was collected into Container 2a. The XAD sorbent trap was capped off and sealed in a plastic baggie labeled Container 2b. The back half of the filter holder, sample line and condenser coil were all rinsed into Container 3 using the same procedure. The contents of the first three impingers were poured directly into Container 4. The impingers were then rinsed with the three solvents above for collection into Container 5. The silica gel impinger contents were weighed for moisture catch determination and returned to the original container.

All of the samples were protected from light and kept below 4 ºC at all times. The samples were delivered in ice chests packed with blue ice to the lab for analysis. The chain of custody and sample login were documented on suitable forms.

Sample Analysis: Analyses were performed by Vista Analytical Laboratory. The XAD resin trap, filter and rinses were analyzed for PAH compounds according to CARB Method 429. The analytical method entails the addition of internal standards in known quantities, matrix-specific extraction of the sample, preliminary fractionating and cleanup of extracts (if necessary) and analysis of the processed extract for PAH. The analyses were conducted using high-resolution capillary column gas chromatography coupled with high-resolution mass spectrometry (HRGC/HRMS).

Reporting: The results have been presented in terms of non-blank-corrected concentrations and mass emission rates. The results for non-detected isomers have been calculated using the full reporting limit (according to the method) and one-half the reporting limit (for health risk assessment determination). Results have been reported in units of concentration (ng/dscm) and mass emissions (lb/hr and lb/MMBtu) of total specified PAH by summing the results of all six specified compounds. Complete documentation of the calculations can be found in Appendix D.6.

4.4.11 Emission Rates, Volumetric Flow Rates and Moisture Content

Emission rates have been calculated in units of lb/MMBTU from the measured concentrations and fuel factors using EPA Method 19. The stack gas volumetric flow rates were also calculated from the fuel heat input rates using Method 19. Emission rates were calculated in units of lb/hr or other mass flow units from the measured concentrations and the calculated volumetric flow rates.

Stack gas velocities were measured using EPA Methods 1 and 2 during each PM and PAH test run. The stack gas moisture contents were measured according to EPA Method 4 in conjunction with the PM and PAH test runs. O_2 and CO_2 concentrations were provided from the concurrent EPA Method 3A test runs. The velocity results were used in calculation of the isokinetic sampling rates for the PM and PAH test runs.

SECTION 5.0

DISCUSSION OF RESULTS

The average test results are presented in Tables 1-1 through 1-10. Summarized results from individual test runs are presented in Tables 5-1 through 5-28. The test results indicate compliance with the permit conditions for the facility.

The samples were collected, recovered and analyzed as described in the test plan submitted in December 2012. The tests were conducted on the days available for both the necessary process conditions and the test crew.

Additional information is included in the appendices. Appendix A contains generic descriptions of standard measurement procedures. Appendix B presents the quality assurance information, including instrument calibration data. Raw field data sheets are included in Appendix C. Appendix D presents the general and specific equations used for the emissions calculations and computer spreadsheet printouts. Appendix E contains the laboratory reports. Excerpts from the facility's CEC and BAAQMD permits are provided for reference in Appendix F.

Sampling Anomalies:

The testing program was conducted as described in the test protocol submitted to the BAAQMD and CEC. The few sampling anomalies included:

- Re-tests of certain emissions conducted to provide more representative results,
- Shifts in the testing schedule to accommodate permit deadlines and process availability, and
- The evaluation and confirmation of the acceptability of the sampling locations.

Such schedule shifts and re-tests are rather common in testing programs on newly-constructed plants as complex as Marsh Landing.

The original test plan included a schedule for testing two turbine units in February 2013 and the other two units in March. Such a schedule was planned to provide for the testing program to be conducted within the deadlines imposed by the permit conditions; certain parts of the BAAQMD permit required that tests be conducted on each unit within 90 days after startup of the unit. Since Unit 1 was started on November 28, 2012, the testing program for Unit 1 was moved up to January 2013 to complete tests before the 90-day deadline. Since the unit had not yet been tuned for rapid startup and shutdown, the startup and shutdown emission tests had to be repeated later. Avogadro had to shuffle the schedule of personnel and equipment, and that affected the quality of the tests for Sulfuric Acid Mist (SAM) emissions.

In the case of testing of emissions during startup and shutdown modes, Unit 1 was first tested on January 28, before tuning of the control system for rapid startup and shutdown. That first set of tests did not represent the emissions that would ensue from the units after proper tuning. Therefore those tests on Unit 1 were repeated on April 20 after the system had been tuned to allow rapid load ramp rates. The original test data are provided in Appendix D.9 in order to document that tests were conducted within the permit deadline for that unit. The results of the re-test are presented in that same appendix, in Tables 5-16 and 5-17, and in Tables 1-5 and 1-6.

The schedule for the original set of tests for SAM emissions on Unit 1 was shifted from February to January, then to later dates in January, as soon as the unit was available for operation at full load (on January 29-30). Unfortunately, the schedule shift meant that Avogadro's SAM testing equipment had just been shipped back from a previously-scheduled test at a coal-fired power plant. The glassware was quickly cleaned to be ready for the test at Marsh Landing, but there was not enough time to conduct a pre-test glassware blank analysis. We did not realize the amount of residual sulfate from that previous testing program on a process that had hundreds of times higher SAM concentrations than those present at Marsh Landing. The results from that original set of SAM tests on Unit 1 indicated higher emissions than would be possible from the sulfur in the natural gas fuel. Therefore, the SAM emission tests on Unit 1 were repeated (on March 12-13) to provide results that represent the actual emissions. The results of the original set of tests are provided in Appendix D.5 and in Table 5-14, in order to document that tests were completed within the permit deadline. The re-test results are provided in the same appendix, and in Tables 5-13 and 1-4.

Avogadro shifted the testing schedule as best possible to fit the times when the process conditions were available. Some of the tests were conducted overnight on a "graveyard shift" schedule, and some on Saturday and Sunday rather than weekdays. Instead of a single test team, we used four Project Managers and various technicians to complete the various parts of the program as units and process conditions became available.

There were sometimes schedule conflicts with test equipment availability, or with tuning conditions of the turbine units. For example, the PM emission tests on Unit 3 were conducted separately from the tests for emissions of NO_X, CO, and other gases, rather than all those tests being conducted at the same time. In that case, we finished what we could at the time, and that made it somewhat easier to schedule and complete the balance of the testing on that unit later. Still, there were no significant anomalies in sampling other than those described above.

The sampling location did not quite meet the minimum criteria of EPA Method 1 for sampling of particulate emissions, but was evaluated and found to be acceptable. There are internal silencer baffles in the lower part of the stack, and they extend to within 2 stack diameters of the sampling ports. Therefore, the ports are 1.88 stack diameters downstream from the top of the silencer baffles; while the baffles could be construed to be a flow disturbance, they may actually help to straighten the flow. The sampling location was evaluated by measuring the yaw angles of the flow at a set of traverse points. The angles were low enough to be well within the criteria for acceptable sampling, so the testing program proceeded using the existing sampling location.

Results Anomalies and Details:

The test results all meet the quality assurance criteria for the test methods used. Some results were below the detection limits, despite very sensitive analytical procedures and/or the long test runs (and large volumes of sample drawn through the sampling trains). The laboratory reports for the various analyses include no significant qualifiers, tags or notes that would indicate anomalies with the laboratory quality assurance checks.

The tests included emissions of Sulfur Oxides (SO_X) calculated from the very sensitive analysis of the Sulfur content of the fuel. The results were calculated from the fuel flow rates, assuming that all the Sulfur in the fuel would become SO_2 emissions. The results were derived this way because the SO_X concentrations in the stack gas were likely to be lower than the detection limit for even 4-hour test runs using standard test methods. Indeed, the 4-hour test runs for sulfuric acid mist (SAM) emissions did not detect SO_2 or SAM, as the detection limit was higher than the amount of SO2 or SAM that could be produced by the low Sulfur content of the fuel. The results of the SAM tests have been reported at the detection limit, and show that the SAM emissions were well below the permit limit.

Other test results that were below the detection limits included most of the Formaldehyde test runs and all the PAH and Benzene test runs. Those results have been reported at the detection limit value. Some data users may need to use ½ the reported “non-detect” values, as some regulations for these toxic emissions may require or allow.

The results for particulate matter (PM) emissions include all the filterable PM regardless of particle size, and the condensable PM (by EPA Method 202) which is regarded as all $PM_{2.5}$ (or PM_{10}). The results as presented therefore represent PM_{10} plus any larger particles in the stack emissions. This approach was used because attempts to measure filterable PM_{10} using EPA Method 201A can include contamination when testing such hot stack gas. Therefore we measured the total filterable PM using EPA Method 5 (which is much less prone to contamination when sampling hot stack gas) in place of the actual filterable PM_{10}.

The PM results have been calculated and presented as requested by the BAAQMD in their guideline document for reporting of emissions near or below the detection limit. The document is commonly referred to as “the QAPP” and provides a means to report the emissions with some evaluation and comparison of the data to the accuracy and uncertainty of such low results.

Process Data:

There was an error in the fuel flow data provided by the plant CEMS DAHS for the Full Load tests on Unit 3 on April 13 and 14, 2013. A correction factor has been calculated and applied to those fuel flows. The plant's instrumentation was corrected shortly after the tests of April 14 to provide corrected fuel flow data. The factor was calculated from the ratio of the average corrected gas flow (from April 19) to the average uncorrected flow (from April 13 and 14); the unit was operating at identical load conditions and similar ambient conditions during those two periods. See Appendix C.2.7 for details.

TABLE 5-1
RESULTS SUMMARY, GASEOUS EMISSIONS
MARSH LANDING GENERATING STATION
CTG-1, MINIMUM LOAD

Parameter	Run 1	Run 2	Run 3	Average
Date:	1/28/13	1/28/13	1/28/13	--
Time:	1237-1307	1325-1355	1407-1434	--
Process Data:				
Fuel Flow, scf/hr:	1,392,898	1,395,019	1,388,258	1,392,058
Gas turbine gross output, MW:	125	125	125	125
Ammonia injection, lb/hr:	149.3	150.7	150.6	150.2
Stack Gas Data:				
O_2, % volume dry:	16.27	16.31	16.30	16.29
CO_2, % volume dry:	2.68	2.70	2.71	2.70
Stack gas flow rate, dscfm:	935,579	945,169	938,544	939,764
Carbon Monoxide:				
ppm volume dry:	0.605	0.549	0.500	0.551
ppm @ 15% O_2:	0.771	0.706	0.641	0.706
lb/hr:	2.459	2.255	2.039	2.251
lb/MMBtu:	0.0017	0.0016	0.0014	0.0016
Ammonia:				
ppm volume dry:	2.367	2.130	2.144	2.213
ppm @ 15% O_2:	3.016	2.738	2.749	2.834

Note: Results shown in italics are below the detection limit, and reported at the detection limit.

TABLE 5-2
RESULTS SUMMARY, GASEOUS EMISSIONS
MARSH LANDING GENERATING STATION
CTG-2, MINIMUM LOAD

Parameter	**Run 1**	**Run 2**	**Run 3**	**Average**
Date:	2/26/13	2/27/13	2/27/13	--
Time:	1613-1643	1013-1043	1118-1148	--
Process Data:				
Fuel Flow, scf/hr:	1,359,880	1,405,120	1,390,930	1,385,310
Gas turbine gross output, MW:	121	127	125	124
Ammonia injection, lb/hr:	203.8	194.1	194.0	197.3
Stack Gas Data:				
O_2, % volume dry:	16.32	16.10	16.15	16.19
CO_2, % volume dry:	2.60	2.77	2.75	2.71
Stack gas flow rate, dscfm:	921,202	908,222	908,514	912,646
Carbon Monoxide:				
ppm volume dry:	0.277	0.305	0.291	0.291
ppm @ 15% O_2:	0.357	0.375	0.361	0.364
lb/hr:	1.109	1.204	1.149	1.154
lb/MMBtu:	0.0008	0.0008	0.0008	0.0008
Ammonia:				
ppm volume dry:	1.882	1.909	2.200	1.997
ppm @ 15% O_2:	2.424	2.346	2.733	2.501

Note: Results shown in italics are below the detection limit, and reported at the detection limit.

TABLE 5-3
RESULTS SUMMARY, GASEOUS EMISSIONS
MARSH LANDING GENERATING STATION
CTG-3, MINIMUM LOAD

Parameter	Run 1	Run 2	Run 3	Average
Date:	3/26/13	3/26/13	3/26/13	--
Time:	1030-1100	1115-1145	1159-1229	--
Process Data:				
Fuel Flow, scf/hr:	1,398,330	1,397,790	1,397,580	1,397,900
Gas turbine gross output, MW:	128	128	128	128
Ammonia injection, lb/hr:	111.5	111.6	111.6	111.6
Stack Gas Data:				
O_2, % volume dry:	16.36	16.41	16.41	16.39
CO_2, % volume dry:	2.63	2.61	2.61	2.62
Stack gas flow rate, dscfm:	957,342	967,629	967,483	964,151
Carbon Monoxide:				
ppm volume dry:	0.267	0.290	0.264	0.274
ppm @ 15% O_2:	0.347	0.381	0.347	0.358
lb/hr:	1.111	1.219	1.110	1.147
lb/MMBtu:	0.0008	0.0009	0.0008	0.0008
Ammonia:				
ppm volume dry:	*0.147*	*0.143*	*0.146*	*0.145*
ppm @ 15% O_2:	*0.191*	*0.187*	*0.192*	*0.190*

Note: Results shown in italics are below the detection limit, and reported at the detection limit.

TABLE 5-4
RESULTS SUMMARY, GASEOUS EMISSIONS
MARSH LANDING GENERATING STATION
CTG-4, MINIMUM LOAD

Parameter	Run 1	Run 2	Run 3	Average
Date:	4/16/13	4/16/13	4/16/13	--
Time:	1949-2019	2025-2055	2102-2132	--
Process Data:				
Fuel Flow, scf/hr:	1,394,300	1,395,180	1,395,640	1,395,040
Gas turbine gross output, MW:	126	126	126	126
Ammonia injection, lb/hr:	198.2	196.8	198.4	197.8
Stack Gas Data:				
O_2, % volume dry:	16.01	16.01	15.97	16.00
CO_2, % volume dry:	2.85	2.85	2.87	2.86
Stack gas flow rate, dscfm:	884,507	885,066	878,174	882,582
Carbon Monoxide:				
ppm volume dry:	0.072	0.024	0.051	0.049
ppm @ 15% O_2:	0.087	0.029	0.061	0.059
lb/hr:	0.277	0.092	0.195	0.188
lb/MMBtu:	0.0002	0.0001	0.0001	0.0001
Ammonia:				
ppm volume dry:	0.397	*0.151*	0.422	0.323
ppm @ 15% O_2:	0.480	*0.182*	0.505	0.389

Note: Results shown in italics are below the detection limit, and reported at the detection limit.

TABLE 5-5
RESULTS SUMMARY, PM10 EMISSION TESTS
MARSH LANDING GENERATING STATION
CTG-1, MAXIMUM LOAD

Parameter	1-PM-1	2-PM-1	3-PM-1	Average
Date:	1/29/13	1/29/13	1/30/13	--
Time:	1010-1435	1604-2021	0842-1301	--
Process Data:				
Fuel Flow, scf/hr:	2,090,350	2,088,355	2,097,670	2,092,125
Gas turbine gross output, MW:	212	212	212	212
Ammonia injection, lb/hr:	217.8	213.4	222.7	218.0
Stack Gas Data:				
O_2, % volume dry	15.66	15.74	15.69	15.70
CO_2, % volume dry	3.02	2.97	3.00	3.00
Stack temperature, °F	828.2	831.0	830.0	829.7
Moisture content, % by volume	6.11	6.29	6.35	6.25
Stack flow rate, dscfm	1,235,446	1,253,403	1,246,911	1,245,253
F½ Particulate Matter:				
gr/dscf	<0.0000	<0.0000	0.0000**	0.0000**
lb/hr	<0.48	<0.50	0.42**	0.30**
lb/MMBtu	<0.0002	<0.0002	0.0002**	0.0001**
B½ Particulate Matter:				
gr/dscf	0.0000**	0.0001	0.0001	0.0001**
lb/hr	0.21**	0.98	0.76	0.64**
lb/MMBtu	0.0001**	0.0005	0.0004	0.0003**
Total Particulate Matter (PM$_{10}$):				
gr/dscf	0.0000**	0.0001**	0.0001**	0.0001**
lb/hr	0.45**	1.23**	1.18**	0.95**
lb/MMBtu	0.0002**	0.0006**	0.0005**	0.0004**
Accuracy ±0.0002 gr/dscf				

Note: The tests were conducted using EPA Methods 5 and 202, and the total PM has been reported as representative of PM$_{10}$ emissions. Results have been reported according to the BAAQMD guidance "QAPP" document.

TABLE 5-6
RESULTS SUMMARY, PM10 EMISSION TESTS MARSH LANDING GENERATING STATION CTG-2, MAXIMUM LOAD

Parameter	1-PM-2	2-PM-2	3-PM-2	Average
Date:	2/28/13	3/6/13	3/6/13	--
Time:	1253-1710	0930-1350	1435-1857	--
Process Data:				
Fuel Flow, scf/hr:	2,015,280	2,041,610	2,048,990	2,035,293
Gas turbine gross output, MW:	202	208	209	206
Ammonia injection, lb/hr:	223.3	229.0	228.9	227.1
Stack Gas Data:				
O_2, % volume dry	15.65	15.66	15.70	15.67
CO_2, % volume dry	2.98	2.94	3.01	2.98
Stack temperature, ºF	820.0	817.8	822.0	819.9
Moisture content, % by volume	6.33	6.59	7.12	6.68
Stack flow rate, dscfm	1,190,503	1,209,281	1,222,521	1,207,435
F½ Particulate Matter:				
gr/dscf	<0.0000	0.0000**	0.0001**	0.0000**
lb/hr	<0.41	0.29**	0.97**	0.48**
lb/MMBtu	<0.0002	0.0001**	0.0005**	0.0002**
B½ Particulate Matter:				
gr/dscf	0.0001**	0.0001	0.0002	0.0001**
lb/hr	0.72**	0.83	1.57	1.04**
lb/MMBtu	0.0003**	0.0004	0.0007	0.0005**
Total Particulate Matter (PM_{10}):				
gr/dscf	0.0001**	0.0001**	0.0002**	0.0001**
lb/hr	0.92**	1.12**	2.53**	1.52**
lb/MMBtu	0.0004**	0.0005**	0.0012**	0.0007**
Accuracy ±0.0002 gr/dscf				

Note: The tests were conducted using EPA Methods 5 and 202, and the total PM has been reported as representative of PM_{10} emissions. Results have been reported according to the BAAQMD guidance "QAPP" document.

TABLE 5-7
RESULTS SUMMARY, PM10 EMISSION TESTS
MARSH LANDING GENERATING STATION
CTG-3, MAXIMUM LOAD

Parameter	1-PM-3	2-PM-3	3-PM-3	Average
Date:	3-19-13	3-27-13	3-27-13	--
Time:	1253-1710	0825-1235	1303-1714	--
Process Data:				
Fuel Flow, scf/hr:	2,050,410	2,039,461	2,033,923	2,041,265
Gas turbine gross output, MW:	209	204	204	206
Ammonia injection, lb/hr:	218.2	160.1	164.8	181.0
Stack Gas Data:				
O_2, % volume dry	15.65	15.69	15.80	15.71
CO_2, % volume dry	2.84	3.00	2.95	2.93
Stack temperature, ºF	818.7	816.8	811.7	815.7
Moisture content, % by volume	5.97	6.47	6.76	6.40
Stack flow rate, dscfm	1,213,673	1,216,460	1,239,323	1,223,152
F½ Particulate Matter:				
gr/dscf	0.0001**	0.0001	0.0001**	0.0001**
lb/hr	0.60**	0.79	0.56**	0.65**
lb/MMBtu	0.0003**	0.0004	0.0003**	0.0003**
B½ Particulate Matter:				
gr/dscf	0.0002	0.0002	0.0002	0.0002
lb/hr	1.63	2.54	2.53	2.22
lb/MMBtu	0.0008	0.0012	0.0012	0.0011
Total Particulate Matter (PM_{10}):				
gr/dscf	0.0002**	0.0003	0.0003**	0.0003**
lb/hr	2.23**	3.34	3.09**	2.87**
lb/MMBtu	0.0011**	0.0016	0.0015**	0.0014**
Accuracy ±0.0002 gr/dscf				

Note: The tests were conducted using EPA Methods 5 and 202, and the total PM has been reported as representative of PM_{10} emissions. Results have been reported according to the BAAQMD guidance "QAPP" document.

TABLE 5-8
RESULTS SUMMARY, PM10 EMISSION TESTS
MARSH LANDING GENERATING STATION
CTG-4, MAXIMUM LOAD

Parameter	**1-PM-4**	**2-PM-4**	**3-PM-4**	**Average**
Date:	4/16/13	4/17/13	4/17/13	--
Time:	2243-0300	0337-0753	0830-1238	--
Process Data:				
Fuel Flow, scf/hr:	2,070,560	2,068,120	2,049,500	2,062,727
Gas turbine gross output, MW:	210	210	207	209
Ammonia injection, lb/hr:	270.6	248.5	271.3	263.5
Stack Gas Data:				
O_2, % volume dry	15.69	15.61	15.68	15.66
CO_2, % volume dry	3.03	3.06	3.03	3.04
Stack temperature, ºF	851.2	850.0	841.0	847.4
Moisture content, % by volume	5.96	5.94	5.21	5.70
Stack flow rate, dscfm	1,232,833	1,212,758	1,217,956	1,221,182
F½ Particulate Matter:				
gr/dscf	0.0001**	0.0003**	<0.0000	0.0001**
lb/hr	0.69**	3.17**	<0.41	1.35**
lb/MMBtu	0.0003**	0.0015**	<0.0002	0.0006**
B½ Particulate Matter:				
gr/dscf	0.0002	0.0001	0.0001	0.0001
lb/hr	1.69	1.34	0.74	1.24
lb/MMBtu	0.0008	0.0006	0.0004	0.0006
Total Particulate Matter (PM_{10}):				
gr/dscf	0.0002**	0.0004**	0.0001**	0.0002**
lb/hr	2.37**	4.51**	0.95**	2.59**
lb/MMBtu	0.0011**	0.0021**	0.0005**	0.0012**
Accuracy ±0.0002 gr/dscf				

Note: The tests were conducted using EPA Methods 5 and 202, and the total PM has been reported as representative of PM_{10} emissions. Results have been reported according to the BAAQMD guidance "QAPP" document.

TABLE 5-9
RESULTS SUMMARY, GASEOUS EMISSIONS
MARSH LANDING GENERATING STATION
CTG-1, MAXIMUM LOAD

Parameter	5-NH3-1	6-NH3-1	7-NH3-1	Average
Date:	1/30/13	1/30/13	1/30/13	--
Time:	0935-1005	1036-1106	1122-1152	--
Process Data:				
Fuel Flow, scf/hr:	2,103,690	2,097,360	2,096,360	2,099,137
Gas turbine gross output, MW:	213	212	211	212
Ammonia injection, lb/hr:	224.6	222.4	220.2	222.4
Stack Gas Data:				
O_2, % volume dry:	15.64	15.71	15.71	15.69
CO_2, % volume dry:	3.03	2.99	2.99	3.00
Stack gas flow rate, dscfm:	1,238,603	1,251,531	1,250,935	1,247,023
Carbon Monoxide:				
ppm volume dry:	0.238	0.125	0.175	0.179
ppm @ 15% O_2:	0.267	0.142	0.199	0.203
lb/hr:	1.281	0.680	0.951	0.971
lb/MMBtu:	0.0006	0.0003	0.0004	0.0005
Nitrogen Oxides:				
ppm volume dry:	1.942	1.879	1.802	1.874
ppm @ 15% O_2:	2.178	2.136	2.049	2.121
lb/hr as NO_2:	17.167	16.784	16.088	16.680
lb/MMBtu as NO_2:	0.0080	0.0078	0.0075	0.0078
Sulfur Oxides (from fuel sulfur)**:**				
fuel sulfur gr/100 scf:	0.158	0.158	0.158	0.158
stack ppm volume dry as SO_2:	0.077	0.076	0.076	0.076
ppm @ 15% O_2 as SO_2:	0.086	0.086	0.086	0.086
lb/hr as SO_2:	0.947	0.944	0.943	0.945
lb/MMBtu as SO_2:	0.0004	0.0004	0.0004	0.0004
Ammonia:				
ppm volume dry:	2.159	2.055	1.981	2.065
ppm @ 15% O_2:	2.422	2.336	2.252	2.336
Precursor Organic Compounds:				
ppm volume dry as CH_4:	0.23	0.16	0.15	0.18
ppm @ 15% O_2 as CH_4:	0.26	0.18	0.18	0.21
lb/hr as CH_4:	0.72	0.49	0.48	0.56
lb/MMBtu as CH_4:	0.00033	0.00023	0.00022	0.00026

Note: Results shown in italics are below the detection limit, and reported at the detection limit.

TABLE 5-10
RESULTS SUMMARY, GASEOUS EMISSIONS MARSH LANDING GENERATING STATION CTG-2, MAXIMUM LOAD

Parameter	**Run 1,2**	**Runs 3, 4**	**Runs 5, 6**	**Average**
Date:	03/06/13	03/06/13	03/06/13	--
Time:	1523-1612	1618-1707	1713-1803	--
Process Data:				
Fuel Flow, scf/hr:	2,045,660	2,045,670	2,051,210	2,047,513
Gas turbine gross output, MW:	208	208	209	208
Ammonia injection, lb/hr:	229.0	228.9	229.0	229.0
Stack Gas Data:				
O_2, % volume dry:	15.73	15.73	15.70	15.72
CO_2, % volume dry:	2.99	3.00	3.01	3.00
Stack gas flow rate, dscfm:	1,227,617	1,226,438	1,223,846	1,225,967
Carbon Monoxide:				
ppm volume dry:	0.10	0.09	0.10	0.10
ppm @ 15% O_2:	0.11	0.11	0.11	0.11
lb/hr:	0.533	0.504	0.532	0.523
lb/MMBtu:	0.0003	0.0002	0.0003	0.0002
Nitrogen Oxides:				
ppm volume dry:	1.91	1.90	1.91	1.91
ppm @ 15% O_2:	2.18	2.16	2.17	2.17
lb/hr as NO_2:	16.717	16.609	16.692	16.673
lb/MMBtu as NO_2:	0.0080	0.0079	0.0079	0.0079
Sulfur Oxides (from fuel sulfur)**:**				
fuel sulfur gr/100 scf:	0.086	0.086	0.086	0.086
stack ppm volume dry as SO_2:	0.04	0.04	0.04	0.04
ppm @ 15% O_2 as SO_2:	0.05	0.05	0.05	0.05
lb/hr as SO_2:	0.502	0.502	0.503	0.502
lb/MMBtu as SO_2:	0.0002	0.0002	0.0002	0.0002
Ammonia:				
ppm volume dry:	1.715	1.349	1.401	1.488
ppm @ 15% O_2:	1.957	1.540	1.590	1.695
Precursor Organic Compounds:				
ppm volume dry as CH_4:	0.51	0.54	0.54	0.53
ppm @ 15% O_2 as CH_4:	0.58	0.62	0.61	0.60
lb/hr as CH_4:	1.549	1.648	1.644	1.614
lb/MMBtu as CH_4:	0.0007	0.0008	0.0008	0.0008

Note: Results shown in italics are below the detection limit, and reported at the detection limit.

TABLE 5-11
RESULTS SUMMARY, GASEOUS EMISSIONS
MARSH LANDING GENERATING STATION
CTG-3, MAXIMUM LOAD

Parameter	Runs 4, 5	Runs 6, 7	Runs 8, 9	Average
Date:	04/13/13	04/14/13	04/14/13	--
Time:	1857-1948	0620-0710	0723-0816	--
Process Data:				
Fuel Flow, scf/hr:	2,013,328	1,998,078	1,998,470	2,003,292
Gas turbine gross output, MW:	200	200	200	200
Ammonia injection, lb/hr:	180.4	198.7	190.9	190.0
Stack Gas Data:				
O_2, % volume dry:	15.76	15.61	15.64	15.67
CO_2, % volume dry:	2.99	3.07	3.05	3.04
Stack gas flow rate, dscfm:	1,217,493	1,174,005	1,180,937	1,190,812
Carbon Monoxide:				
ppm volume dry:	0.09	0.06	0.07	0.07
ppm @ 15% O_2:	0.10	0.06	0.08	0.08
lb/hr:	0.473	0.296	0.372	0.380
lb/MMBtu:	0.0002	0.0001	0.0002	0.0002
Nitrogen Oxides:				
ppm volume dry:	1.85	1.96	1.94	1.92
ppm @ 15% O_2:	2.12	2.19	2.17	2.16
lb/hr as NO_2:	16.062	16.456	16.313	16.277
lb/MMBtu as NO_2:	0.0078	0.0080	0.0079	0.0079
Sulfur Oxides (from fuel sulfur)**:**				
fuel sulfur gr/100 scf:	0.107	0.107	0.107	0.107
stack ppm volume dry as SO_2:	0.05	0.05	0.05	0.05
ppm @ 15% O_2 as SO_2:	0.06	0.06	0.06	0.06
lb/hr as SO_2:	0.615	0.610	0.610	0.612
lb/MMBtu as SO_2:	0.0003	0.0003	0.0003	0.0003
Ammonia:				
ppm volume dry:	*0.158*	*0.161*	0.608	0.309
ppm @ 15% O_2:	*0.181*	*0.179*	0.686	0.349
Precursor Organic Compounds:				
ppm volume dry as CH_4:	0.91	0.93	0.74	0.86
ppm @ 15% O_2 as CH_4:	1.05	1.03	0.83	0.97
lb/hr as CH_4:	2.766	2.702	2.163	2.543
lb/MMBtu as CH_4:	0.0013	0.0013	0.0011	0.0012

Note: Results shown in italics are below the detection limit, and reported at the detection limit.

TABLE 5-12
RESULTS SUMMARY, GASEOUS EMISSIONS
MARSH LANDING GENERATING STATION
CTG-4, MAXIMUM LOAD

Parameter	Runs 2, 3	Runs 4, 5	Runs 6, 7	Average
Date:	04/16-17/13	04/17/13	04/17/13	--
Time:	2334-0023	0032-0121	0127-0215	--
Process Data:				
Fuel Flow, scf/hr:	2,069,340	2,072,985	2,072,175	2,071,500
Gas turbine gross output, MW:	209	209	210	210
Ammonia injection, lb/hr:	276.0	271.6	262.2	269.9
Stack Gas Data:				
O_2, % volume dry:	15.69	15.71	15.70	15.70
CO_2, % volume dry:	3.03	3.03	3.04	3.03
Stack gas flow rate, dscfm:	1,230,948	1,237,842	1,234,992	1,234,594
Carbon Monoxide:				
ppm volume dry:	0.13	0.05	0.10	0.09
ppm @ 15% O_2:	0.15	0.06	0.11	0.11
lb/hr:	0.711	0.274	0.523	0.503
lb/MMBtu:	0.0003	0.0001	0.0002	0.0002
Nitrogen Oxides:				
ppm volume dry:	1.58	1.59	1.58	1.58
ppm @ 15% O_2:	1.78	1.81	1.79	1.79
lb/hr as NO_2:	13.85	14.06	13.92	13.94
lb/MMBtu as NO_2:	0.0065	0.0066	0.0065	0.0066
Sulfur Oxides (from fuel sulfur)**:**				
fuel sulfur gr/100 scf:	0.135	0.135	0.135	0.135
stack ppm volume dry as SO_2:	0.06	0.06	0.06	0.06
ppm @ 15% O_2 as SO_2:	0.07	0.07	0.07	0.07
lb/hr as SO_2:	0.797	0.799	0.798	0.798
lb/MMBtu as SO_2:	0.0004	0.0004	0.0004	0.0004
Ammonia:				
ppm volume dry:	2.315	2.119	2.460	2.298
ppm @ 15% O_2:	2.632	2.405	2.796	2.611
Precursor Organic Compounds:				
ppm volume dry as CH_4:	0.04	0.12	0.10	0.09
ppm @ 15% O_2 as CH_4:	0.05	0.14	0.11	0.10
lb/hr as CH_4:	0.126	0.379	0.292	0.265
lb/MMBtu as CH_4:	0.0001	0.0002	0.0001	0.0001

Note: Results shown in italics are below the detection limit, and reported at the detection limit.

TABLE 5-13

RESULTS SUMMARY, SULFURIC ACID MIST EMISSION RETEST

MARSH LANDING GENERATING STATION

CTG-1, MAXIMUM LOAD

Parameter	**1-SAM-1R**	**2-SAM-1R**	**3-SAM-1R**	**Average**
Date:	3/12/13	3/12/13	3/13/13	--
Time:	1132-1532	1638-2038	0900-1300	--
Process Data:				
Fuel Flow, scf/hr:	1,976,520	1,948,710	2,003,990	1,976,407
Gas turbine gross output, MW:	200.6	197.2	202.4	200.0
Ammonia injection, lb/hr:	206.2	202.3	202.4	204.8
Stack Gas Data:				
O_2, % volume dry	15.90	16.00	16.00	15.97
Moisture content, % by volume	6.20	6.59	6.89	6.56
Stack flow rate, dscfm	1,238,867	1,246,363	1,276,775	1,254,001
Sulfur Dioxide (SO_2):				
ppm volume dry as SO_2	*0.046*	*0.042*	*0.043*	*0.044*
lb/hr as SO_2	*0.56*	*0.52*	*0.55*	*0.55*
lb/MMBtu as SO_2	*0.00028*	*0.00026*	*0.00027*	*0.00027*
Sulfuric Acid / SO_3:				
ppm volume dry as SO_3	*0.082*	*0.080*	*0.086*	*0.083*
lb/hr as H_2SO_4	*1.55*	*1.52*	*1.68*	*1.58*
lb/MMBtu as H_2SO_4	*0.00076*	*0.00075*	*0.00081*	*0.00077*
Tons/year, as H_2SO_4	5.30	5.25	5.66	5.41

Note: - Results in italics were below the detection limit.
Sulfuric acid mist (SAM) and SO_3 are counted together as liquid and gaseous phases of the same compound. The measurement was made by controlled condensation sampling train (EPA CTM-013).
Entire plant tons/ year results are based on the maximum permitted heat input to the facility of 13,994,976 MMBtu/year per Condition 14 of the ATC.

TABLE 5-14
RESULTS SUMMARY, SULFURIC ACID MIST ORIGINAL EMISSION TESTS MARSH LANDING GENERATING STATION CTG-1, MAXIMUM LOAD

Parameter	1-SAM-1	2-SAM-1	3-SAM-1	Average
Date:	1/29/13	1/29/13	1/30/13	--
Time:	1046-1446	1605-2005	0842-1242	--
Process Data:				
Fuel Flow, scf/hr:	2,087,730	2,087,420	2,098,650	2,091,267
Gas turbine gross output, MW:	211.7	211.7	212.0	211.8
Ammonia injection, lb/hr:	216.6	213.2	223.1	217.6
Stack Gas Data:				
O_2, % volume dry	15.66	15.74	15.69	15.70
Moisture content, % by volume	6.61	7.81	7.70	7.37
Stack flow rate, dscfm	1,235,446	1,253,403	1,246,911	1,245,253
Sulfur Dioxide (SO_2):				
ppm volume dry as SO_2	0.17	0.20	0.19	0.19
lb/hr as SO_2	2.1	2.5	2.4	2.3
lb/MMBtu as SO_2	0.0010	0.0012	0.0011	0.0011
Sulfuric Acid / SO_3:				
ppm volume dry as SO_3	1.23	1.06	0.12	0.80
lb/hr as H_2SO_4	23.2	20.1	2.3	15.2
lb/MMBtu as H_2SO_4	0.0108	0.0094	0.0011	0.0071
Tons/year, as H_2SO_4	75.77	65.84	7.52	49.71

Note: Sulfuric acid mist (SAM) and SO_3 are counted together as liquid and gaseous phases of the same compound. The measurement was made by controlled condensation sampling train (EPA CTM-013). Entire plant tons/ year results are based on the maximum permitted heat input to the facility of 13,994,976 MMBtu/year per Condition 14 of the ATC.

TABLE 5-15
RESULTS SUMMARY, SULFURIC ACID MIST EMISSION TESTS
MARSH LANDING GENERATING STATION
CTG-2, MAXIMUM LOAD

Parameter	**1-SAM-2**	**2-SAM-2**	**3-SAM-2**	**Average**
Date:	3/12/13	3/12/13	3/13/13	--
Time:	1215-1615	1645-2045	0950-1350	--
Process Data:				
Fuel Flow, scf/hr:	1,964,190	1,943,860	1,982,970	1,963,670
Gas turbine gross output, MW:	198.2	195.3	198.1	197.2
Ammonia injection, lb/hr:	217.3	209.8	213.8	213.6
Stack Gas Data:				
O_2, % volume dry	15.80	15.90	15.80	15.83
Moisture content, % by volume	7.28	6.28	6.97	6.84
Stack flow rate, dscfm	1,206,045	1,217,080	1,212,289	1,211,804
Sulfur Dioxide (SO_2):				
ppm volume dry as SO_2	*0.047*	*0.044*	*0.047*	*0.046*
lb/hr as SO_2	*0.57*	*0.54*	*0.57*	*0.56*
lb/MMBtu as SO_2	*0.00028*	*0.00027*	*0.00028*	*0.00028*
Sulfuric Acid / SO_3:				
ppm volume dry as SO_3	*0.085*	*0.085*	*0.094*	*0.088*
lb/hr as H_2SO_4	*1.57*	*1.57*	*1.74*	*1.63*
lb/MMBtu as H_2SO_4	*0.00077*	*0.00078*	*0.00085*	*0.00080*
Tons/year, as H_2SO_4	*5.37*	*5.44*	*5.92*	*5.58*

Note: - Results in italics were below the detection limit.

Sulfuric acid mist (SAM) and SO_3 are counted together as liquid and gaseous phases of the same compound. The measurement was made by controlled condensation sampling train (EPA CTM-013). Entire plant tons/ year results are based on the maximum permitted heat input to the facility of 13,994,976 MMBtu/year per Condition 14 of the ATC.

TABLE 5-16
RESULTS SUMMARY, STARTUP EMISSIONS
MARSH LANDING GENERATING STATION
CTG-1

Parameter	1-Start-1	2-Start-1	3-Start-1	Average
Date:	4/20/13	4/20/13	4/20/13	--
Time:	1139-1155	1401-1416	1450-1500	--
Process Data:				
Startup sequence duration, min	14	14	10	12.7
Fuel, total scf per startup	204,169	190,418	118,222	170,936
Carbon Monoxide:				
Total lb emitted per startup	12.9	14.5	10.1	12.5
Nitrogen Oxides, NO_X as NO_2:				
Total lb emitted per startup	10.7	7.1	7.9	8.6
Non-methane non-ethane HC:				
Total lb emitted per startup	11.5	10.9	9.4	10.6

Note: These results were calculated from the data from one-minute intervals during each test run. See Appendix D.9 for details of each test run.

TABLE 5-17
RESULTS SUMMARY, SHUTDOWN EMISSIONS
MARSH LANDING GENERATING STATION
CTG-1

Parameter	1-Shut-1	2-Shut-1	3-Shut-1	Average
Date:	4/20/13	4/20/13	4/20/13	--
Time:	1222-1228	1427-1433	1510-1516	--
Process Data:				
Shutdown sequence, min	6	6	6	6.0
Fuel, total scf per shutdown	81,446	81,944	94,610	86,000
Carbon Monoxide:				
Total lb emitted per shutdown	5.7	7.4	8.2	7.1
Nitrogen Oxides, NO_X as NO_2:				
Total lb emitted per shutdown	1.3	1.9	2.0	1.7
Non-methane non-ethane HC:				
Total lb emitted per shutdown	2.0	2.5	4.0	2.8

Note: These results were calculated from the data from one-minute intervals during each test run. See Appendix D.9 for details of each test run.

TABLE 5-18
RESULTS SUMMARY, STARTUP EMISSIONS
MARSH LANDING GENERATING STATION
CTG-2

Parameter	**1-Start-2**	**2-Start-2**	**3-Start-2**	**Average**
Date:	3/13/13	3/13/13	3/13/13	--
Time:	1410-1428	1520-1538	1629-1646	--
Process Data:				
Startup sequence duration, min	18	18	17	17.7
Fuel, total scf per startup	181,728	184,334	134,440	166,834
Carbon Monoxide:				
Total lb emitted per startup	43.3	32.3	26.8	34.2
Nitrogen Oxides, NO_X as NO_2:				
Total lb emitted per startup	9.4	10.5	9.0	9.6
Non-methane non-ethane HC:				
Total lb emitted per startup	8.7	12.7	3.8	8.4

Note: These results were calculated from the data from one-minute intervals during each test run. See Appendix D.9 for details of each test run.

TABLE 5-19
RESULTS SUMMARY, SHUTDOWN EMISSIONS
MARSH LANDING GENERATING STATION
CTG-2

Parameter	**1-Shut-2**	**2-Shut-2**	**3-Shut-2**	**Average**
Date:	3/13/13	3/13/13	3/13/13	--
Time:	1311-1324	1446-1456	1557-1607	--
Process Data:				
Shutdown sequence, min	13	10	10	11.0
Fuel, total scf per shutdown	244,543	129,779	136,610	170,311
Carbon Monoxide:				
Total lb emitted per shutdown	13.0	11.3	11.8	12.0
Nitrogen Oxides, NO_X as NO_2:				
Total lb emitted per shutdown	4.2	3.1	3.1	3.5
Non-methane non-ethane HC:				
Total lb emitted per shutdown	2.1	6.2	4.9	4.4

Note: These results were calculated from the data from one-minute intervals during each test run. See Appendix D.9 for details of each test run.

TABLE 5-20
RESULTS SUMMARY, STARTUP EMISSIONS
MARSH LANDING GENERATING STATION
CTG-3

Parameter	1-Start-3	2-Start-3	3-Start-3	Average
Date:	4/21/13	4/21/13	4/21/13	--
Time:	0918-0928	1140-1149	1224-1234	--
Process Data:				
Startup sequence duration, min	10	9	10	
Fuel, total scf per startup	115,579	112,092	105,533	
Carbon Monoxide:				
Total lb emitted per startup	25.1	12.7	10.8	16.2
Nitrogen Oxides, NO_X as NO_2:				
Total lb emitted per startup	5.0	4.4	4.7	4.7
Non-methane non-ethane HC:				
Total lb emitted per startup	7.9	5.9	6.0	6.6

Note: These results were calculated from the data from one-minute intervals during each test run. See Appendix D.9 for details of each test run.

TABLE 5-21
RESULTS SUMMARY, SHUTDOWN EMISSIONS
MARSH LANDING GENERATING STATION
CTG-3

Parameter	1-Shut-3	2-Shut-3	3-Shut-3	Average
Date:	4/21/13	4/21/13	4/21/13	--
Time:	1002-1007	1200-1206	1248-1253	
Process Data:				
Shutdown sequence, min	5	6	5	5.3
Fuel, total scf per shutdown	72,425	88,652	75,104	78,725
Carbon Monoxide:				
Total lb emitted per shutdown	7.2	4.6	6.5	6.1
Nitrogen Oxides, NO_X as NO_2:				
Total lb emitted per shutdown	3.0	2.9	3.0	2.9
Non-methane non-ethane HC:				
Total lb emitted per shutdown	2.3	2.8	2.9	2.7

Note: These results were calculated from the data from one-minute intervals during each test run. See Appendix D.9 for details of each test run.

TABLE 5-22
RESULTS SUMMARY, STARTUP EMISSIONS
MARSH LANDING GENERATING STATION
CTG-4

Parameter	1-Start-4	2-Start-4	3-Start-4	Average
Date:	4/20/13	4/20/13	4/20/13	--
Time:	1843-1853	1926-1936	2012-2021	--
Process Data:				
Startup sequence duration, min	10	11	8	9.7
Fuel, total scf per startup	109,628	117,087	129,303	118,673
Carbon Monoxide:				
Total lb emitted per startup	6.1	5.3	4.9	5.4
Nitrogen Oxides, NO_X as NO_2:				
Total lb emitted per startup	3.6	3.9	3.4	3.6
Non-methane non-ethane HC:				
Total lb emitted per startup	5.0	9.0	6.5	6.9

Note: These results were calculated from the data from one-minute intervals during each test run. See Appendix D.9 for details of each test run.

TABLE 5-23
RESULTS SUMMARY, SHUTDOWN EMISSIONS
MARSH LANDING GENERATING STATION
CTG-4

Parameter	1-Shut-4	2-Shut-4	3-Shut-4	Average
Date:	4/20/13	4/20/13	4/20/13	--
Time:	1903-1908	1948-1953	2032-2039	--
Process Data:				
Shutdown sequence, min	5	5	6	5.3
Fuel, total scf per shutdown	53,367	51,876	73,123	59,455
Carbon Monoxide:				
Total lb emitted per shutdown	2.5	4.9	4.2	3.9
Nitrogen Oxides, NO_X as NO_2:				
Total lb emitted per shutdown	1.6	1.7	1.7	1.7
Non-methane non-ethane HC:				
Total lb emitted per shutdown	5.6	3.1	4.8	4.5

Note: These results were calculated from the data from one-minute intervals during each test run. See Appendix D.9 for details of each test run.

TABLE 5-24
RESULTS SUMMARY
FORMALDEHYDE EMISSION TESTS
MARSH LANDING GENERATING STATION
CTG-2, MINIMUM LOAD

Run Number	**1-F-2-Min**	**2-F-2-Min**	**3-F-2-Min**	**Average**
Date:	2/26/13	2/27/13	2/27/13	--
Time:	1442-1858	0920-1338	1406-1818	--
Process Data:				
Fuel Flow, scf/hr:	1,362,120	1,392,820	1,372,660	1,375,867
Gas turbine gross output, MW:	121	125	125	124
Ammonia injection, lb/hr:	205.4	194.3	194.0	197.9
Stack Gas Data:				
O_2, % volume dry	16.36	16.13	16.19	16.23
CO_2, % volume dry	2.606	2.758	2.686	2.683
Stack flow rate, dscfm	930,849	905,934	904,195	913,659
Formaldehyde				
Concentration, ppb vol dry	21.95	3.70	ND< 2.20	< 9.28
Emission Rate, lb/hr	0.095	0.016	ND< 0.010	< 0.040
Emission Rate, lb/MMBTU	6.77E-05	1.09E-05	ND< 6.73E-06	< 2.84E-05

Note: The formaldehyde results were calculated from the blank-corrected concentrations, but the non-blank corrected and CARB reporting limit emissions can be found in Appendix D. Results with a "ND<" denote that a species was not detected in sample and is reported at the detection limit. Results with "<" were below the limit of detection in at least one sample or sample fraction, but not in all samples or sample fractions.

TABLE 5-25
RESULTS SUMMARY
FORMALDEHYDE EMISSION TESTS
MARSH LANDING GENERATING STATION
CTG-2, MAXIMUM LOAD

Run Number	**1-F-2-Max**	**2-F-2-Max**	**3-F-2-Max**	**Average**
Date:	2/28/13	3/6/13	3/6/13	--
Time:	1254-1704	0930-1348	1445-1857	--
Process Data:				
Fuel Flow, scf/hr:	2,015,050	2,041,620	2,049,290	2,035,320
Gas turbine gross output, MW:	121	208	208	179
Ammonia injection, lb/hr:	223.3	229.0	228.9	227.1
Stack Gas Data:				
O_2, % volume dry	15.85	15.88	15.70	15.81
CO_2, % volume dry	2.920	2.877	2.998	2.932
Stack flow rate, dscfm	1,237,982	1,261,802	1,222,700	1,240,828
Formaldehyde				
Concentration, ppb vol. dry	< 11.17	ND<2.85	ND<25.58	< 13.20
Emission Rate, lb/hr	< 0.064	ND<0.017	ND<0.147	< 0.076
Emission Rate, lb/MMBTU	< 3.11E-05	ND<7.97E-06	ND<7.00E-05	< 3.64E-05

Note: The formaldehyde results were calculated from the blank-corrected concentrations, but the non-blank corrected and CARB reporting limit emissions can be found in Appendix D. Results with a "ND<" denote that a species was not detected in sample and is reported at the detection limit. Results with "<" were below the limit of detection in at least one sample or sample fraction, but not in all samples or sample fractions.

TABLE 5-26
RESULTS SUMMARY
POLYCYCLIC AROMATIC HYDROCARBON EMISSION TESTS
MARSH LANDING GENERATING STATION
CTG-2, MINIMUM LOAD

TEST NO.	1-PAH-2	2-PAH-2	3-PAH-2			**AVERAGE**
Date	2/26/13	2/27/13	2/27/13			--
Time	1442-1858	0920-1338	1406-1818			--
Process Data:						
Fuel Flow, scf/hr	1,362,120	1,392,820	1,372,660			1,375,867
Gross output, MW	121	125	125			124
Ammonia, lb/hr	205.4	194.3	194.0			197.9
Stack Gas Data:						
O_2, % volume dry	16.36	16.13	16.19			16.22
CO_2, % volume dry	2.606	2.758	2.686			2.683
Stack flow, dscfm	930,849	905,934	904,195			913,659
Specified PAH	**ng/dscm**	**ng/dscm**	**ng/dscm**	**ng/dscm**	**lb/hr**	**lb/MMBtu**
Benz(a)anthracene	ND< 2.187	ND< 2.287	ND< 2.247	ND< 2.240	ND< 7.66E-06	ND< 5.40E-09
Benzo(b)fluoranthene	ND< 2.187	ND< 2.287	ND< 2.247	ND< 2.240	ND< 7.66E-06	ND< 5.40E-09
Benzo(k)fluoranthene	ND< 2.187	ND< 2.287	ND< 2.247	ND< 2.240	ND< 7.66E-06	ND< 5.40E-09
Benzo(a)pyrene	ND< 2.187	ND< 2.287	ND< 2.247	ND< 2.240	ND< 7.66E-06	ND< 5.40E-09
Indeno(1,2,3-cd)pyrene	ND< 2.187	ND< 2.287	ND< 2.247	ND< 2.240	ND< 7.66E-06	ND< 5.40E-09
Dibenzo(a,h)anthracene	ND< 2.187	ND< 2.287	ND< 2.247	ND< 2.240	ND< 7.66E-06	ND< 5.40E-09
Total Specified PAH	ND< 13.12	ND< 13.72	ND< 13.48	ND< 13.44	ND< 4.60E-05	ND< 3.24E-08

Note: Results with a “ND<” denote that a species was not detected in sample and is reported at the detection limit

TABLE 5-27
RESULTS SUMMARY
POLYCYCLIC AROMATIC HYDROCARBON EMISSION TESTS
MARSH LANDING GENERATING STATION
CTG-2, MAXIMUM LOAD

TEST NO.	1-PAH-2	2-PAH-2	3-PAH-2			**AVERAGE**
Date	2/28/13	3/6/13	3/6/13			--
Time	1254-1706	0930-1348	1445-1857			--
Process Data:						
Fuel Flow, scf/hr	2,015,050	2,041,620	2,049,290			2,035,320
Gross output, MW	121	208	208			179
Ammonia, lb/hr	223.3	229.0	228.9			227.1
Stack Gas Data:						
O_2, % volume dry	15.85	15.88	15.70			15.81
CO_2, % volume dry	2.920	2.877	2.998			2.932
Stack flow, dscfm	1,237,982	1,261,802	1,222,700			1,240,828
Specified PAH	**ng/dscm**	**ng/dscm**	**ng/dscm**	**ng/dscm**	**lb/hr**	**lb/MMBtu**
Benz(a)anthracene	ND< 2.430	ND< 2.339	ND< 2.336	ND< 2.368	ND< 1.10E-05	ND< 5.24E-09
Benzo(b)fluoranthene	ND< 2.430	ND< 2.339	ND< 2.336	ND< 2.368	ND< 1.10E-05	ND< 5.24E-09
Benzo(k)fluoranthene	ND< 2.430	ND< 2.339	ND< 2.336	ND< 2.368	ND< 1.10E-05	ND< 5.24E-09
Benzo(a)pyrene	ND< 2.430	ND< 2.339	ND< 2.336	ND< 2.368	ND< 1.10E-05	ND< 5.24E-09
Indeno(1,2,3-cd)pyrene	ND< 2.430	ND< 2.339	ND< 2.336	ND< 2.368	ND< 1.10E-05	ND< 5.24E-09
Dibenzo(a,h)anthracene	ND< 2.430	ND< 2.339	ND< 2.336	ND< 2.368	ND< 1.10E-05	ND< 5.24E-09
Total Specified PAH	ND< 14.58	ND< 14.03	ND< 14.02	ND< 14.21	ND< 6.47E-05	ND< 3.15E-08

Note: Results with a "ND<" denote that a species was not detected in sample and is reported at the detection limit. Results with "<" were below the limit of detection in at least one sample or sample fraction, but not in all samples or sample fractions. The detection limit value was used for all species below the limit of detection.

TABLE 5-28
RESULTS SUMMARY
BENZENE EMISSION TESTS
MARSH LANDING GENERATING STATION
CTG-2, MINIMUM LOAD

Run Number	**1-VOC**	**2-VOC**	**3-VOC**	**Average**
Date:	2/26/13	2/27/13	2/27/13	--
Time:	1442-1512	0920-0950	1406-1436	--
Process Data:				
Fuel Flow, scf/hr	1,362,120	1,392,820	1,372,660	1,375,867
Gross output, MW	121	125	125	124
Ammonia, lb/hr	205.4	194.3	194.0	197.9
Stack Gas Data:				
O_2, % volume dry	16.39	16.13	16.19	16.24
CO_2, % volume dry	2.606	2.758	2.686	2.683
Stack flow rate, dscfm	930,849	905,934	904,195	913,659
Benzene:				
Concentration, ppb vd	ND< 1.00	ND< 0.96	ND< 0.95	ND< 0.97
Emission Rate, lb/hr	ND< 0.011	ND< 0.011	ND< 0.010	ND< 0.012
Em. Rate, lb/MMBtu	ND< 8.12E-06	ND< 7.37E-06	ND< 7.39E-06	ND< 7.62E-06

Note: Results with a ND< denote that the compound was not detected in sample and is reported at the detection limit. These test runs were all conducted during the PAH test runs, so the average stack flow, O_2 and CO_2 data were all taken from corresponding PAH runs.

TABLE 5-29
RESULTS SUMMARY
BENZENE EMISSION TESTS
MARSH LANDING GENERATING STATION
CTG-2, MAXIMUM LOAD

Run Number	**1-VOC**	**2-VOC**	**3-VOC**	**Average**
Date:	2/28/13	3/6/13	3/6/13	--
Time:	1253-1323	0930-1000	1435-1505	--
Process Data:				
Fuel Flow, scf/hr	2,015,050	2,041,620	2,049,290	2,035,320
Gross output, MW	121	208	208	179
Ammonia, lb/hr	223.3	229.0	228.9	227.1
Stack Gas Data:				
O_2, % volume dry	15.85	15.88	15.70	15.81
CO_2, % volume dry	2.920	2.877	2.998	2.932
Stack flow rate, dscfm	1,237,982	1,261,802	1,222,700	1,240,828
Benzene:				
Concentration, ppb vd	ND< 0.88	ND< 0.89	ND< 0.88	ND< 0.88
Emission Rate, lb/hr	ND< 0.013	ND< 0.014	ND< 0.013	ND< 0.013
Em. Rate, lb/MMBTU	ND< 7.10E-06	ND< 6.49E-06	ND< 6.20E-06	ND< 6.59E-06

Note: Results with a ND< denote that the compound was not detected in sample and is reported at the detection limit. These test runs were all conducted during the PAH test runs, so the average stack flow, O_2 and CO_2 data were all taken from corresponding PAH runs.

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