ENVIRON

Enclosure 3

Demonstration of NOx Emission Controls for Gas Compressor Engines

A Study for Northeast Texas

Presented by

ENVIRON

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Today's Presentation

- Project background
- Design of retrofits and testing
- Implementation of retrofits
- Emissions reductions demonstrated
- Cost effectiveness of retrofits
- Next steps

Project Background

- 2002 NETAC emission inventory
  - Reductions for point source and mobile emissions
  - Estimates 36 tpd NOx from uncontrolled compressor engines
- Need to demonstrate effectiveness of retrofit technology to facilitate implementation
- NETAC obtains EPA funds to demonstrate retrofit technologies for gas compressor engines

Uncontrolled Gas Compressor Engines

Used in natural gas gathering system to transmit produced gas

Existing Conditions

- Engine characteristics
  - Natural gas fueled
  - Reciprocating
  - Generally less than 500 hp
  - Operated constantly
- Uncontrolled engines have high emission rate (EPA's estimates 12 grams NOx / horsepower-hour)
- Control technology for this type of engine is readily available

Rich-Burn Engine Control Technology

- Considerations: Availability, effectiveness, reliability and cost
- Nonselective Catalytic Reduction
  - Installed on thousands of stationary IC engines in the US[2]. Vendors easily identified.
  - EPA identified as capable of the greatest degree of emission reduction in near term[1]
  - Existing implementation on engines of greater than 500 hp shows low maintenance requirement
  - Cost estimated at less than $10,000 per engine

[1]EPA, 2002. *Final Rule for Cleaner Large industrial Spark-Ignition Engines, Recreational Marine Diesel Engines, and Recreational Vehicles*.

[2]MECA. 1997. *Emission Control Technologies for Stationary Internal Combustion Engines: Status Report*.

Non-Selective Catalytic Reduction (NSCR)

- "Three-Way", reduces NOx, CO and HC
- Functions best when air:fuel ratio is accurately controlled
- Greater than 90% NOx reduction efficiency in some applications
- Equipment needed:
  - Catalyst
  - Air:Fuel ratio controller
  - Solar power supply

Design of Testing Procedure

- Testing methods based on EPA and California Air Resource Board programs
  - Before installation testing
  - Install retrofit
  - After installation testing
    - 100 hours after installation
    - 1000+ hours after installation, “longevity”
- Two emissions testing methods used
  - Third-party contractor uses EPA methods
  - Hanover uses portable gas analyzer

Industry Partner

- December 2002 meeting with compressor owners/operators
- The Hanover Company agrees to participate in pilot program
  - Started with 3 engines in January
  - Added 2 additional engines in July

ID	Unit 70640	Unit 74236	Unit 70024	Unit 75558	Unit 72386
Make & Model	CAT G342NA	CAT 3306TA	CAT G342TA	CAT 3306TA	CAT 3306NA
Rated Hp	225	225	265	220	145

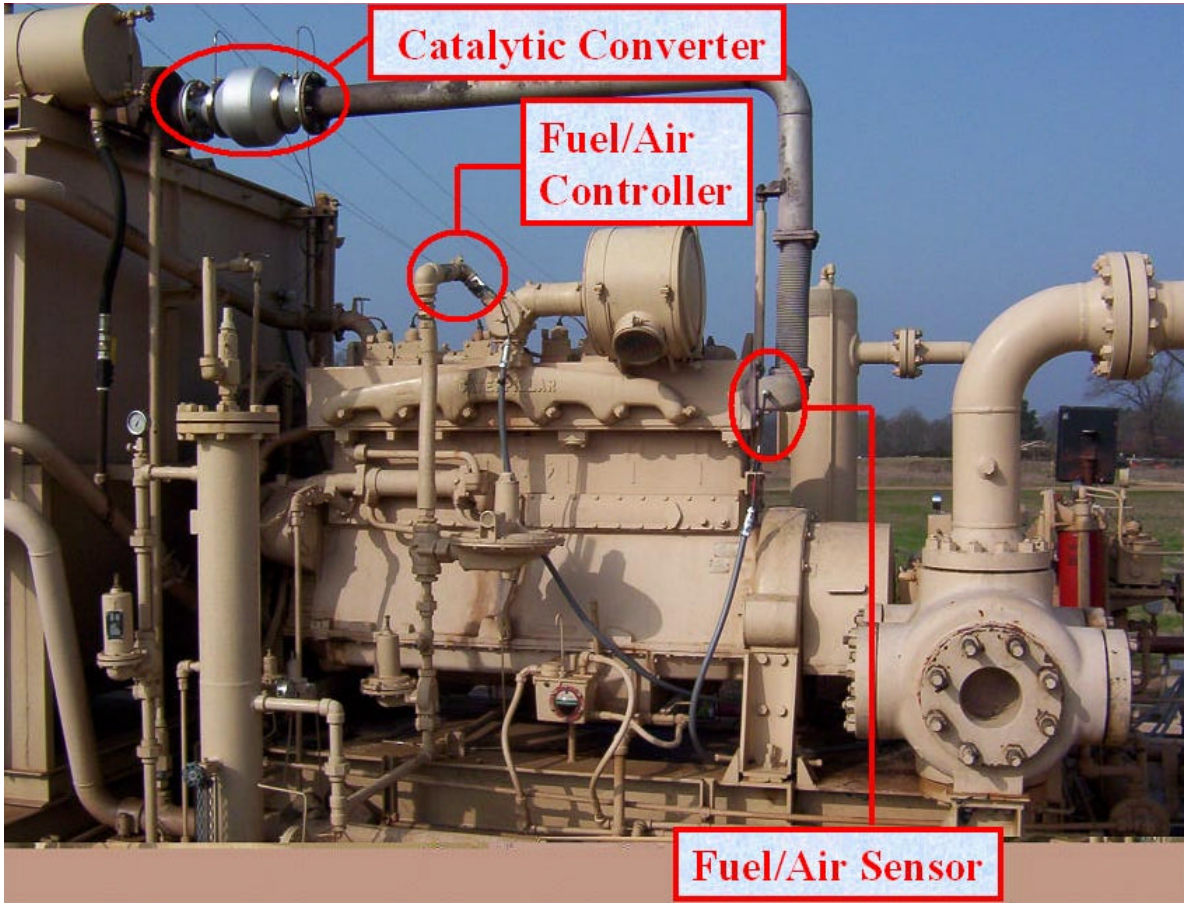
Baseline NOx Emission Rates

Engine	Rated Hp	3rd Party Test Result	Hanover Test Result
Unit 70640	225	2089 ppmv	2072 ppmv
		11.6 g/hp-hr	
Unit 74236	203	3159 ppmv	2793 ppmv
		13.0 g/hp-hr	
Unit 70024	265	2509 ppmv	2331 ppmv
		13.3 g/hp-hr	
Unit 75558	220	**12.7 g/hp-hr**	
Unit 72386	145	**12.4 g/hp-hr**	

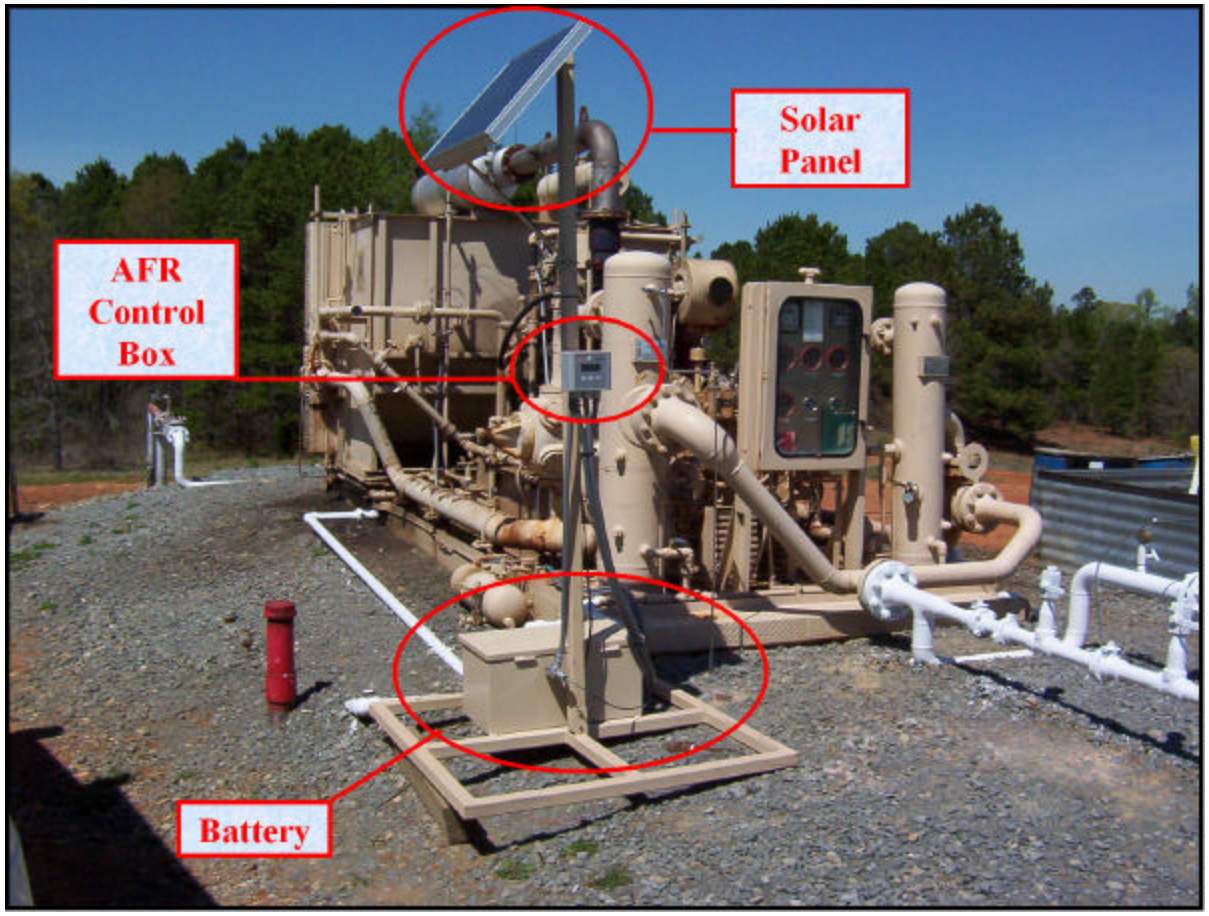
Installation of NSCR Retrofit

- Equipment
  - Three-way Catalyst; $1,800 - $2,130
  - Fuel/air controller; $4,290
  - Solar power supply; $1,450
- Retrofits installed by Hanover staff
  - 3 engines in February
  - 2 engines in August

System Installed – Controls



System Installed – Power Supply



Results of After Installation Testing

NOx Emission Rates After 100 Hours

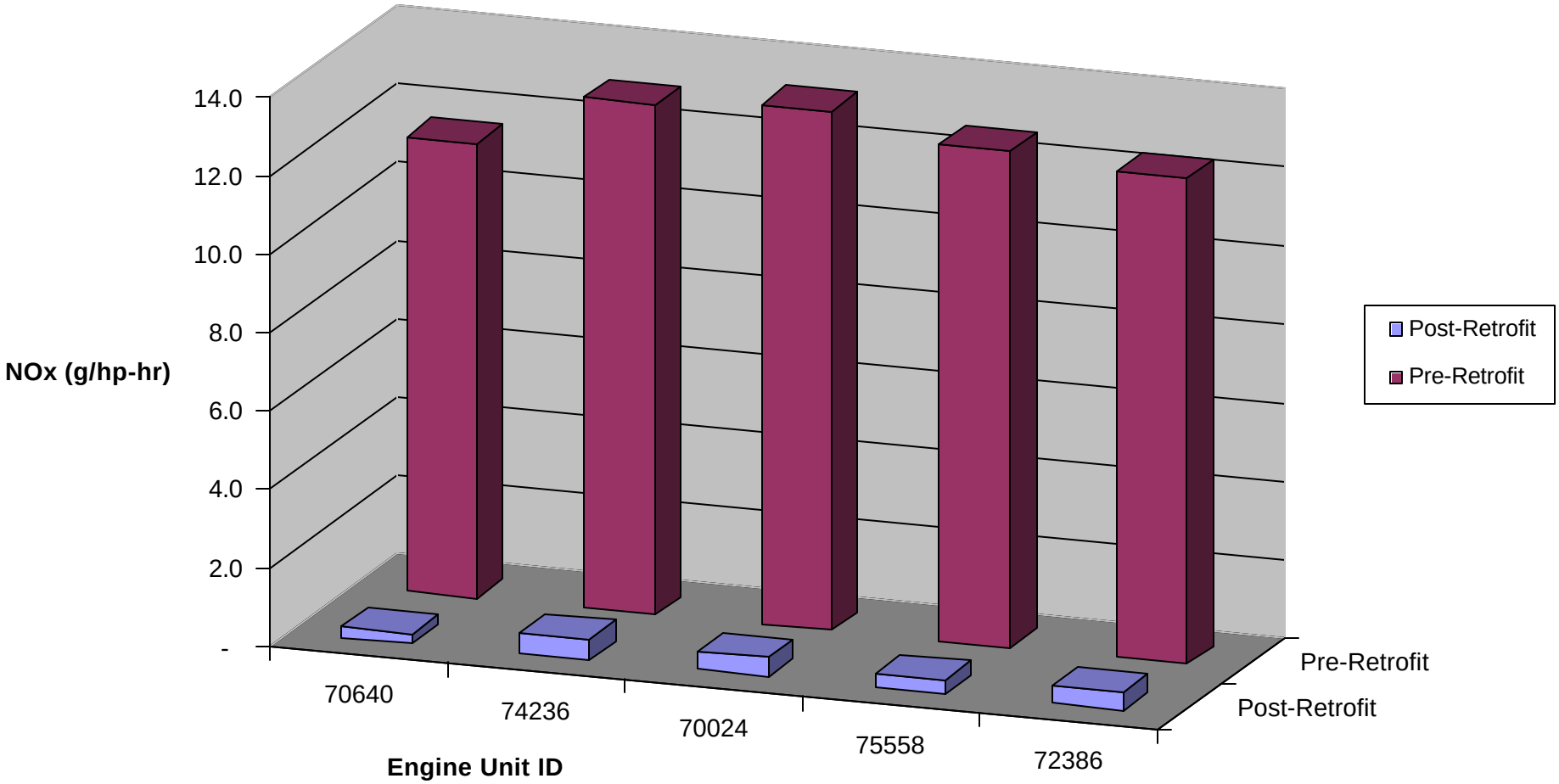
Engine	Rated Hp	3rd Party Test Result	Hanover Test Result
Unit 70640	225	49 ppmv	35 ppmv
		0.3 g/hp-hr	
Unit 74236	203	52 ppmv	35 ppmv
		0.5 g/hp-hr	
Unit 70024	265	67 ppmv	50 ppmv
		0.5 g/hp-hr	
Unit 75558	220	**0.4 g/hp-hr**	
Unit 72386	145	**0.5 g/hp-hr**	

Comparison of Before and After Installation

Comparison Using 3rd Party Results

Engine	70640	74236	70024	75558	72386
Before (g NOx/hp-hr)	11.6	13.0	13.3	12.7	12.4
After (g NOx/hp-hr)	0.3	0.5	0.5	0.4	0.5
NOx Control Efficiency	97%	96%	96%	97%	96%

Emission Rates Before and After Retrofit



Results of Longevity Testing

NOx Emission Rates After 1000+ Hours

Engine	Time Elapsed (hrs)	NOx Emission Rates (g/hp-hr)		NOx Reduction by Catalyst
		Pre-Catalyst	Post-Catalyst	
70640	4,000+	26.81	0.99	96%
74236	4,000+	20.77	0.85	96%
75558	1,000	14.16	0.40	97%
72386	1,000	10.65	0.40	96%

Summary of Emission Testing Results

- NSCR technology retrofit achieves dramatic emissions reductions
- Portable gas analyzer test method demonstrates utility
- Catalysts continue to achieve very high emissions reductions after 4,000+ hours

Cost Effectiveness Estimate

- Annual emissions reductions
  - Actual emission rates
  - 8000 hours per year
  - Load from average of loading during testing
- Annualized costs
  - Equipment purchase cost
  - Estimated installation cost
  - Anticipated maintenance costs
  - TCEQ stipulated 3 percent discount rate
  - Conservative estimate of five year project life

Annual Emissions Reductions

Average of five engines

Before Installation	NOx emission rate (g/hp-hr)	12.6
	Estimated annual NOx emission (ton / yr)	12.7
After Installation	NOx emission rate (g/hp-hr)	0.4
	Estimated annual NOx emission (ton / yr)	0.4
Reduction Achieved	Reduction (tons / yr)	**12.3**
	Reduction (percent)	97%

Anticipated Maintenance Costs

- Power Supply
  - Solar Panel (clean glass)
  - Battery (gel type; 3-4 year life)
- Fuel/Air Regulator
  - Controller (no maintenance)
  - Oxygen sensor (recommended replacement every 90 days, $50)
- Catalyst (wash every 2 years, $150 - $300; 5-10 year life)

Cost of Engine Retrofit

Average Equipment Cost		
	Catalytic Converter	$ 1,932
	AFR Controller Kit	$ 4,290
	Solar Power Unit	$ 1,450
Approximate Installation Cost		
	16 employee-hours x $80/hr	$ 1,280
Annual Operation and Maintenance Costs		
	Clean Catalyst	$ 150/yr
	Replace Oxygen Sensor	$ 200/yr
	Replace Battery	$ 50/yr
Present Value of Project Costs		$ 10,622
Annualized Project Costs (5 years @ 3%)		**$ 2,252 / yr**

NSCR Retrofit Cost Effectiveness

- Average Cost Effectiveness
  - Annual emission reduction = 12.3 tons NOx
  - Annualized costs = $2,250
  - $2,250 / 12.3 tons NOx = **$183 / ton NOx**
- With 10 year life, effectiveness is $112 / ton NOx
- With 5 year life and strict adherence to Texas Emission Reduction Program's guidelines, effectiveness is $185 / ton NOx

Additional Cost Considerations

- Potential negative impact on fuel economy
  - Adjusting air/fuel ratio to near stoichiometric
  - Two engines showed 11 and 17 percent increases in fuel consumption based on carbon balance
- NSCR system can be damaged
  - Excessively contaminated fuel
  - Overloaded engine (backfire)

Potential for Widespread Application

- Texas Emission Reduction Plan (TERP)
  - $9,381,231 designated for NETAC area
  - Pilot project demonstrates these criteria met:
    - *Verified* to emit 25 percent less NOx than prior to retrofit
    - Cost effectiveness less than $13,000 per ton NOx
- Potential Air Quality Benefit

  If the entire sum of TERP funds were dedicated to compressor engine retrofits, over 10 thousand tons per year of NOx emissions could be eliminated in the NETAC area

Next Steps

- TCEQ determination that retrofits meet TERP criteria
- Outreach to compressor engine operators
- Improve inventory of existing compressor engine emissions to better quantify potential emission reductions