



**GE Industrial AeroDerivative  
Gas Turbines**

GE Power Systems.  
One Neumann Way, S158  
Cincinnati, OH 45215-1988  
Phone: (513) 552-5925  
Fax: (513) 552-5059

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Orange Cogeneration Limited Partnership  
1125 US 98 South, Suite 100  
Lakeland, FL 33801

Attn: Wade Smith

I have been intimately involved in the development of the Dry Low Emissions (DLE) Combustion Technology for the GE LM engines in the past 9 years. I have published 3 peer-reviewed papers describing this technology and have about 15 patents.

I have reviewed the attached technical approach of utilizing inlet water injection (SPRINT) as well as the limited injection of water or steam in the pilot dome to achieve lower NOx emissions. This is a logical approach in that the flame temperature is reduced by both of these approaches. It is well known in the industry that reduction of the combustor flame temperature will lead to reduced NOx emissions. The concept will need to be developed beyond a simple demonstration to ensure that a sufficient margin exists between the demonstrated capability and emissions regulations. Combustor dynamics and operating maps will have to be generated and validated.

The plan calls for demonstration of NOx reduction by injection of water in the pilot dome using a well-developed and characterized single cup/module test rig. Once an acceptable NOx reduction has been demonstrated the decision to proceed with an engine test can be taken. The engine test will help generate operating parameters, and maps for the enhancement of the DLE technology.

In summary, the approach to NOx reduction is practical. The development program, laid out by the team, is logical and has a reasonable potential for success.

Sincerely,

Narendra Joshi, PhD.  
Product Development Program Mgr  
GE Industrial AeroDerivative Gas Turbines



## GE Industrial Aerodervative Gas Turbines

# Orange Cogeneration 15 PPM Emissions Attainment Program

RB Hook GE-IAD Technical Program Mgr.

Eric Kress GE-IAD Systems Engineer

9/2/99

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## Agenda

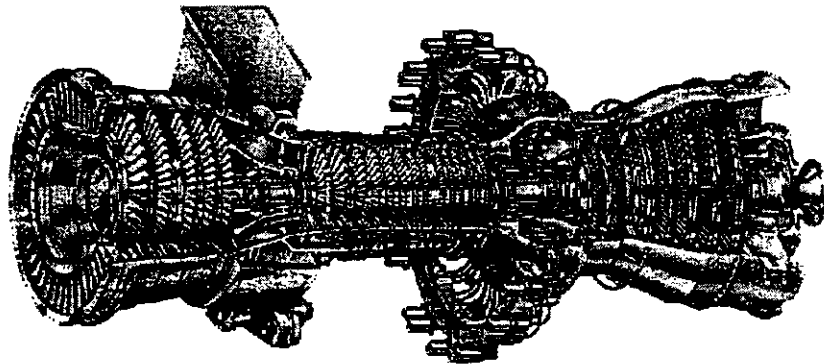
- Review of LM6000 System
- Results of SPRINT™ Feasibility Testing at Bartow
- Selective Water Injection Concept - Damp Low Emissions
- Program Plan
- Conclusion

Job ID#4612

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## LM6000 Dry Low Emissions Systems



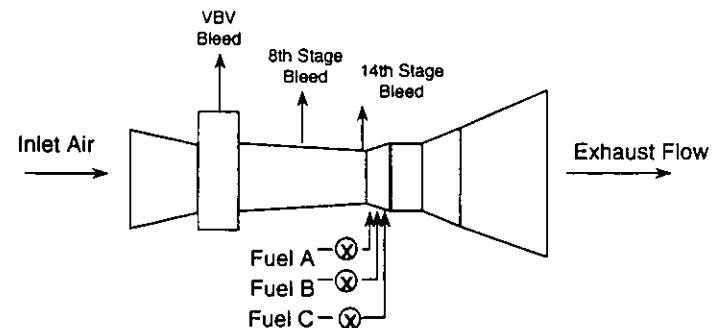
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## GE - IAD Approach to Dry Low Emissions

- Combination of fuel and air staging: Required for premix operation from start to full power
- Triple annular combustor: Compact, minimal cooling air required, and facilitates fuel staging



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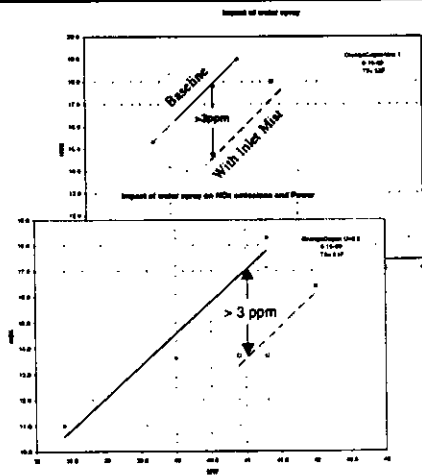
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## Sprint Testing Conducted on Bartow Units

### Inlet water injection testing

- 3ppm reduction @ constant power
- 15.5 ppm @ Orangecco guarantee level
- 0.9-1.3 MW power increase @ constant NOx

Water wash injection system known to produce nonuniform spray



**SPRINT™ test reduced NOx 3ppm on Orange Cogen engines - Demonstrated 15 PPM / 16 PPM at rated power**

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## SPRINT™ Testing - Conclusions

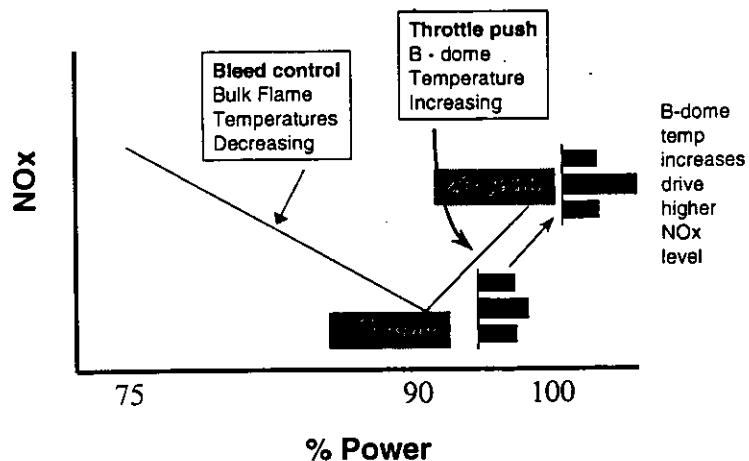
- Testing nearly achieved 15 ppm at rated power
- Improvements can be anticipated with production SPRINT™ system
  - Spray distribution
  - Atomization
- Margin for deterioration an issue

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## NOx Characteristics of Triple Annular Combustor

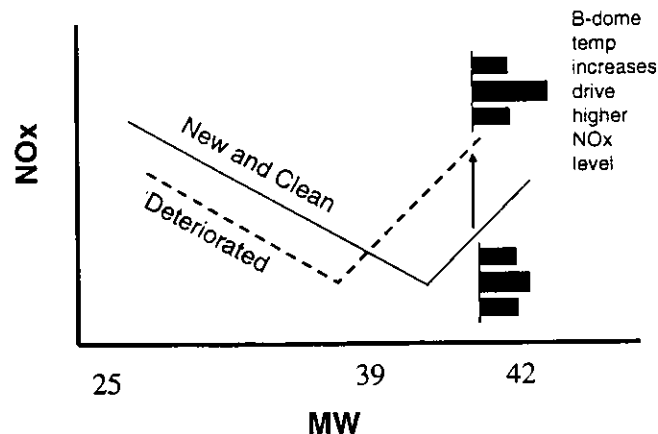


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## Deterioration and NOx emissions



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## Selective Injection - Strategy & Objectives

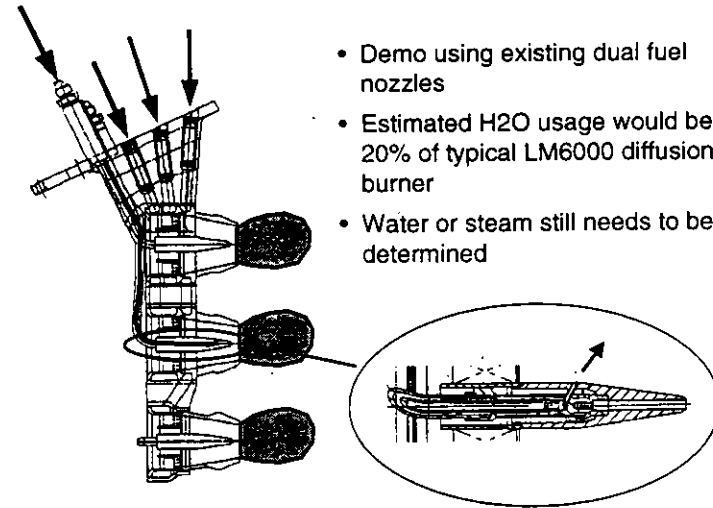
- “Manage” B dome temperatures
- Achieve entitlement level on NOx
- Offset deterioration

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## Selective Injection



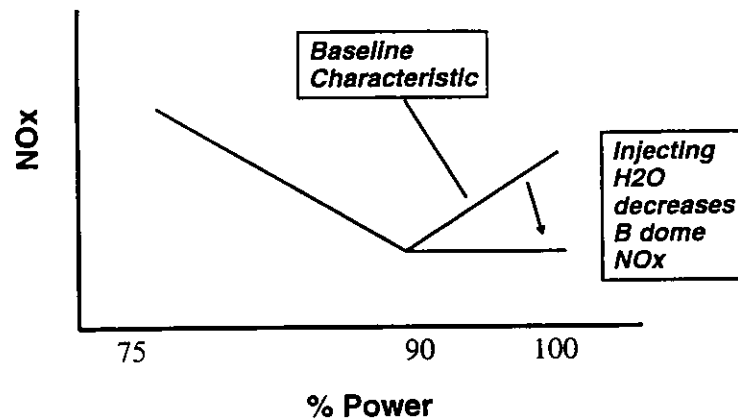
- Demo using existing dual fuel nozzles
- Estimated H<sub>2</sub>O usage would be 10-20% of typical LM6000 diffusion burner
- Water or steam still needs to be determined

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## NOx Characteristics of Triple Annular Combustor with selective H<sub>2</sub>O injection

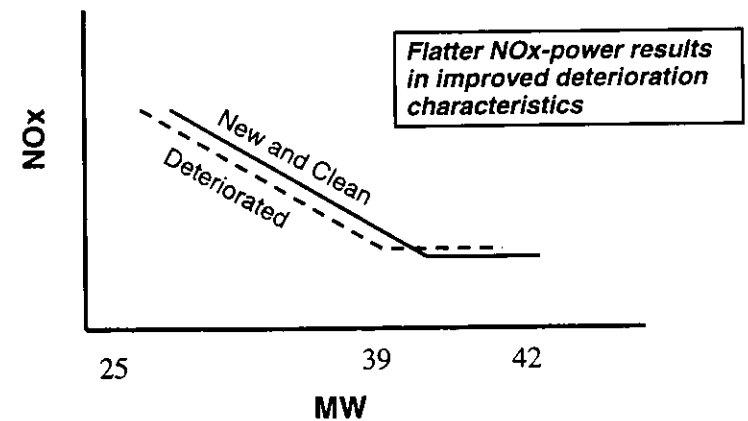


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## Deterioration and NOx with Selective H<sub>2</sub>O Injection

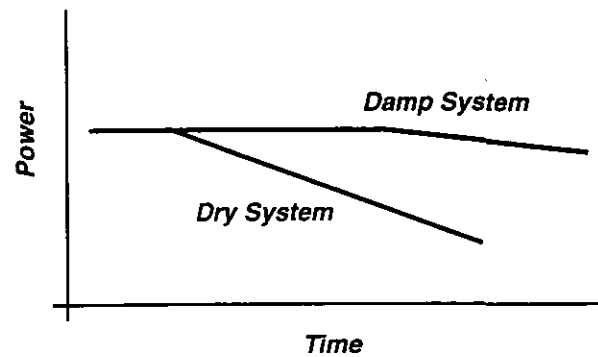


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## Deterioration of Power vs Time

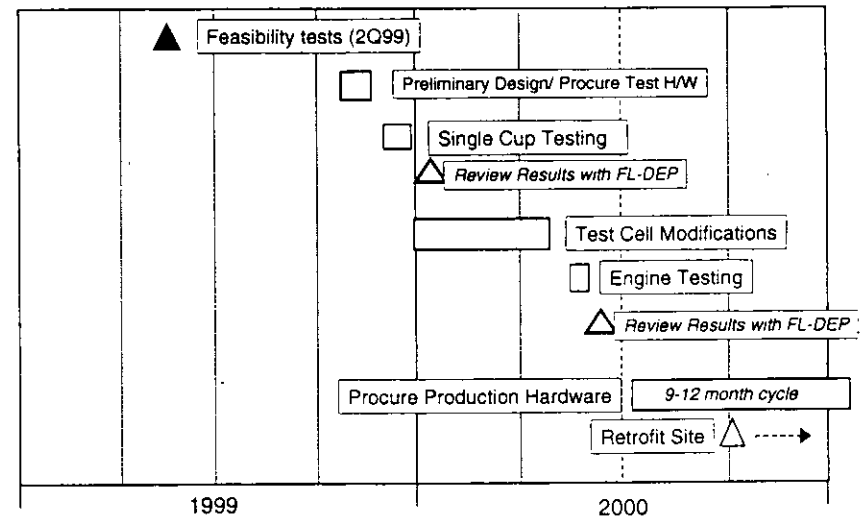


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## Water Injection Program Schedule



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## Summary

**SPRINT Feasibility demonstrated near attainment of permit level**

**15-16 PPM Demonstrated**

**Selective H<sub>2</sub>O injection will**

- further reduce NO<sub>x</sub>
- Offset deterioration

**Potential for 12-13 ppm**

**Need engine test to confirm**

**Combination of these two concepts will achieve emissions objectives for Bartow Plant**

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## Proposal

- GE proposes to invest in damp technology to meet permit limits at Bartow
  - Avoids SCR solution and increased operating costs for CSW
  - Avoids issues of ammonia slip at site
  - Leads to better control technology in aeroderivative gas turbine
- Confidence that this will lead to a successful solution
- Will involve FL- DEP in technical status reviews
- At time of engine test a go-no go determination will be made
  - If required, we are poised to initiate PO for SCR retrofit at that time

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