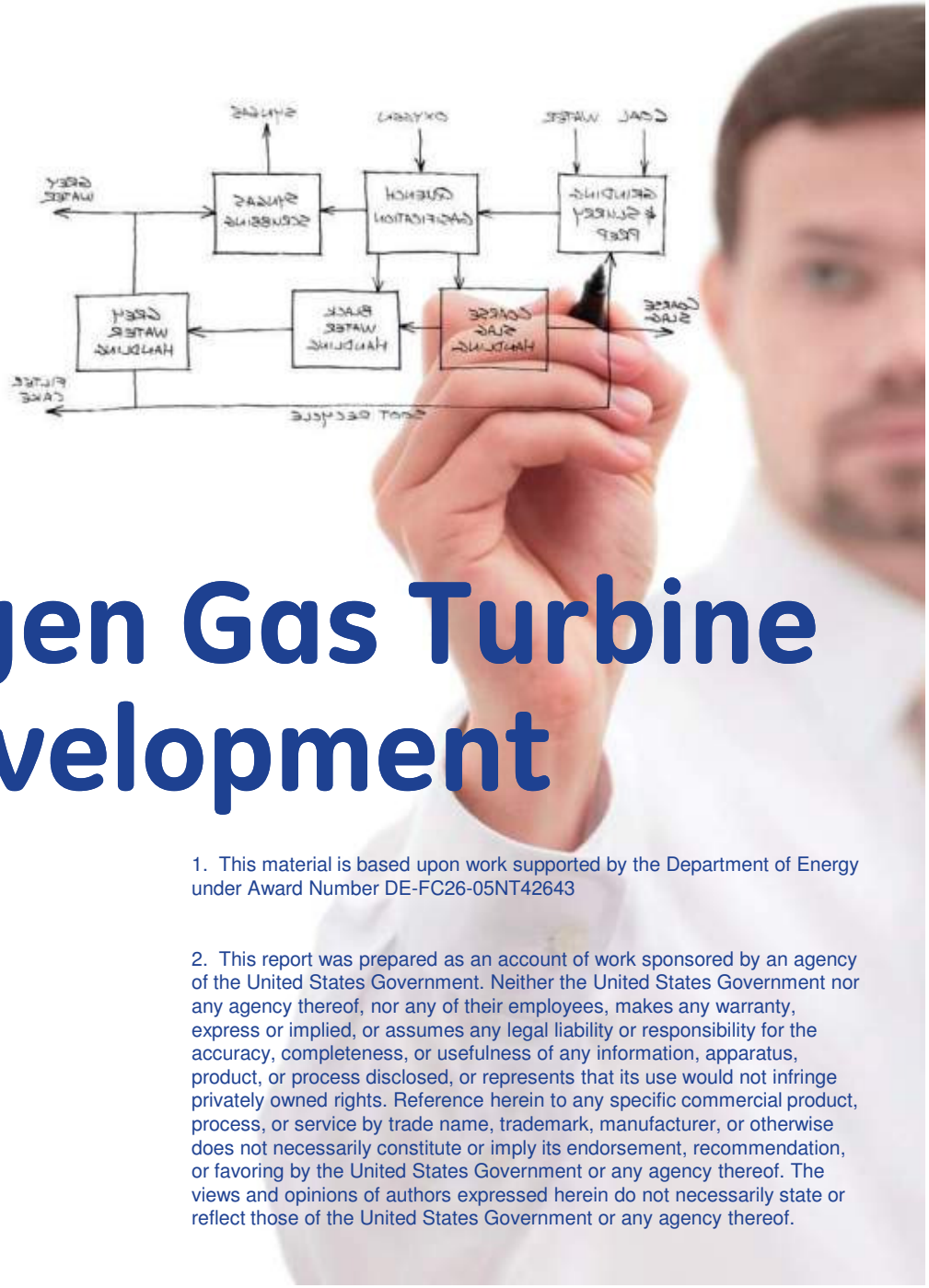
GE
Energy



Syngas/Hydrogen Gas Turbine Technology Development

Roger Schonewald

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60Hz IGCC Reference Plant

- 630 MW output*
- 37-39% efficiency HHV*
- 85% coal to power availability*
- $2.2B total installed cost*
- Lower emissions than SCPC
- Wide range of bituminous coals
- Guaranteed output, heat rate, emissions & schedule
- Carbon capture ready

*Coal, site, operating condition dependant
**Compared to SCPC coal plants

Emissions**

- 33% less NOx
- 75% less SOx
- 40% less PM10
- 30% less water

Fuel Flexibility

- Up to 30% coke blends
- Up to 7.5 lb/MWh sulfur, 14% ash
- 3,000 ppmv chlorides
- Natural gas or distillate backup fuel

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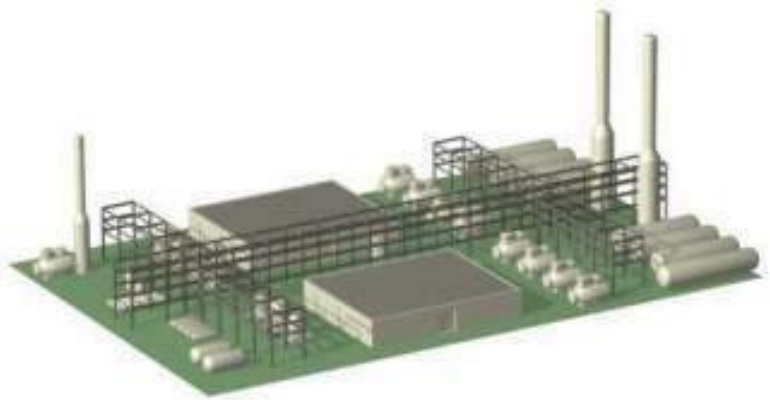
GE's Carbon Island™



- 585 MW output (from 630 MW)
- 33% efficient (from 38.5%)
- Tie-ins matched GT outages (Minimum plant downtime)

IGCC retrofit solution

- Option to GE's IGCC plant design
- Fits in allocated plot space
- Integrated with existing AGR
- Commercially proven technologies
  - Shift and low-temp gas cooling
  - Supplementary AGR
  - CO_2 enrichment
  - CO_2 compression
- 50-65% carbon capture

➔NGCC equivalent carbon footprint

Note: Illinois Basin Coal on ISO site with proven technology...Performance and CAPEX are coal-dependant

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Duke Energy Edwardsport IGCC

Engineering completion…85%

Procurement completion…47%

RSC shells arrived on site June ’09

Dec. 2009*: Gasifiers arrive at site

~1,400 Duke, GE, Bechtel & craft personnel at site

Gasification island, Sept. ‘09

RSC assembly, Sept. ‘09

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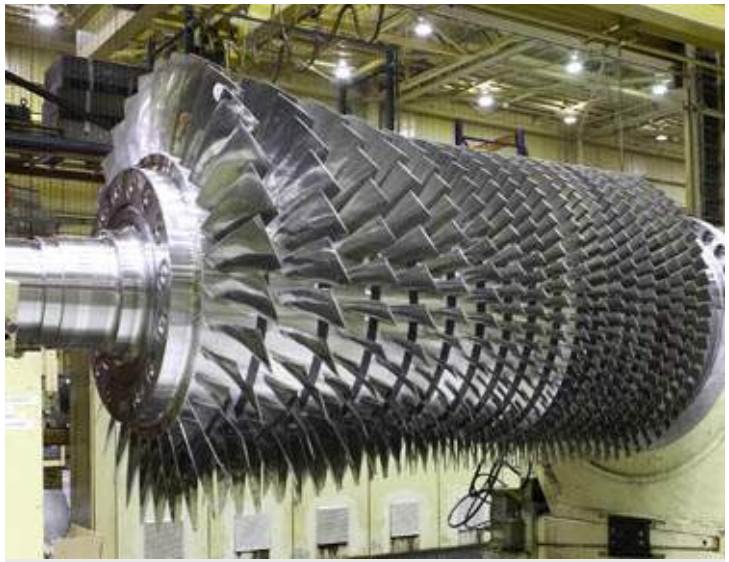
*Expected date.

Duke Energy Edwardsport IGCC

March 2010*:	Training on controls/simulator
May 2010*:	Turbines arrive at site
2Q 2011*:	1st fire (turbines) on natural gas
4Q 2011*:	Turbine operation on syngas



Syngas turbine compressor, manufacturing, Sept. '09

Controls/Simulation, Sept. '09

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*Expected date.

What is the future for gasification?

The industry has…

Proven technology

Potential projects

What is needed to move CCS forward…

Government incentives & indemnities

Commercial scale projects to drive the experience curve to the next level

We need to show the world the **solutions** to energy security, GHG.

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DOE Advanced H_2/IGCC Gas Turbine Program

DOE Goals

Performance:

- +2 to 3 % pts efficiency by 2010
- +3 to 5 % pts efficiency (total) by 2015

Emissions:

- 2 ppm NOx by 2015
- Fuel flexibility – syngas & H_2

Cost

- Contribute to IGCC capital cost reduction

Program Timeline

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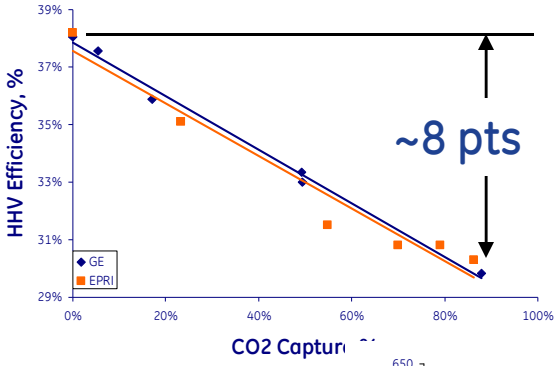
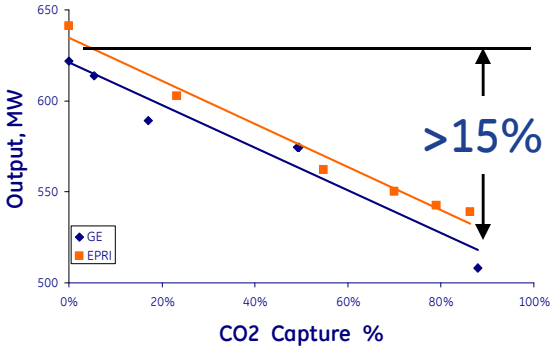
Gas Turbine Technology Advancement to Offset Much Of CCS Penalty

- **Combustion**
  - Higher temperature, lower emissions operation with highly reactive fuels
- **Turbine**
  - Higher component efficiency with higher flow rates
- **Materials**
  - Higher temperature materials and coatings in an IGCC/H2 environment
- **Systems**
  - Improved GT Integration with BOP





Turbine

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Combustion Technology for Advanced H2 Gas Turbine

DOE H2 Turbine Combustion Goals

Emissions:

- 2 ppm NOx @ 15% O_2 by 2015

Fuel-Flexibility:

- Operability for Syngas and C-Free Syngas
- Natural Gas operability also desirable

Efficiency:

- Moderate combustor pressure drop
- Support increased firing temperature capability

Cost:

- Costs near natural gas DLN combustors

Flame Visualization Testing

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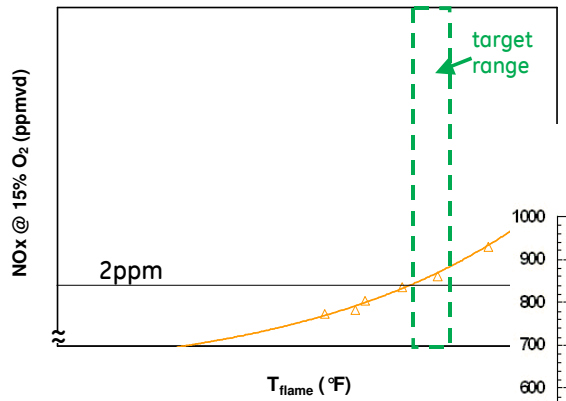
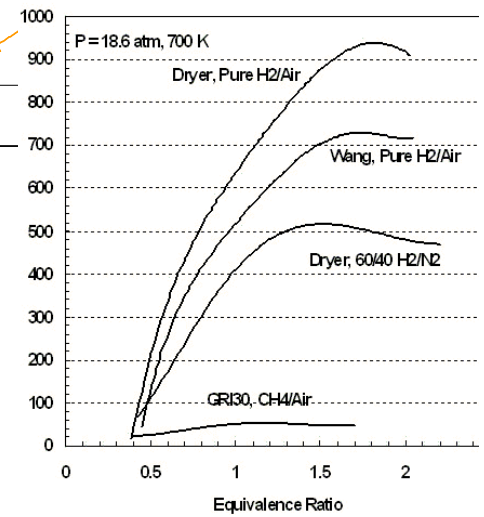
Combustion Challenges

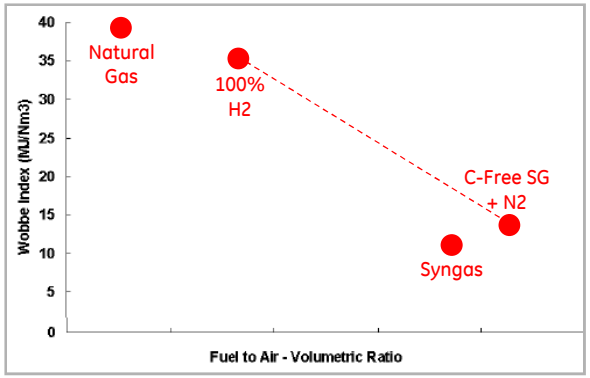
- NO_x
  - 2 ppm goal aggressive at higher Tfire conditions required to meet program goals.
- Flashback
  - Higher flame speed than Natural Gas
  - Low ignition energy
  - Wide flammability range
  - Faster combustion kinetics
- Dynamics
  - Premixed H_2 flame shapes far different than methane
- Fuel Flexibility
  - Designing for a wide fuel range (syngas, C-free syngas, natural gas) increases the challenge

Entitlement (perfectly premixed) NOx Data



Flame Speed





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Combustion Technology Advancement

Technology Basics

- Modeling & Design
- Entitlement Data
- Concept Characteristics

- Fundamental Research

Nozzle Scale

- NG / Syngas / High H_2
- Emissions, Dynamics, Lean Blow Out

Full Can Scale

- NG / Syngas / High H_2
- Combustor Performance

Gas Turbine

- Simple & Combined Cycle
- Part load to Full Load

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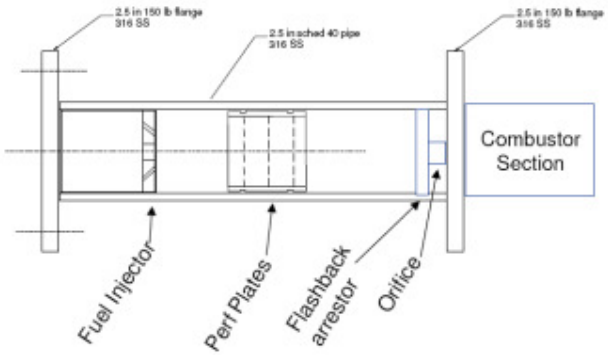
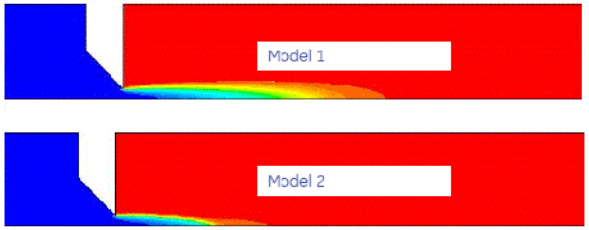
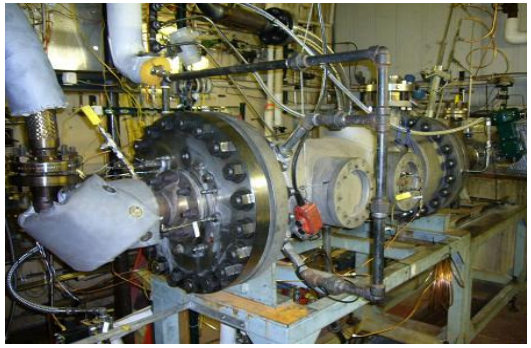
Combustion Progress



Perfectly Premixed Testing

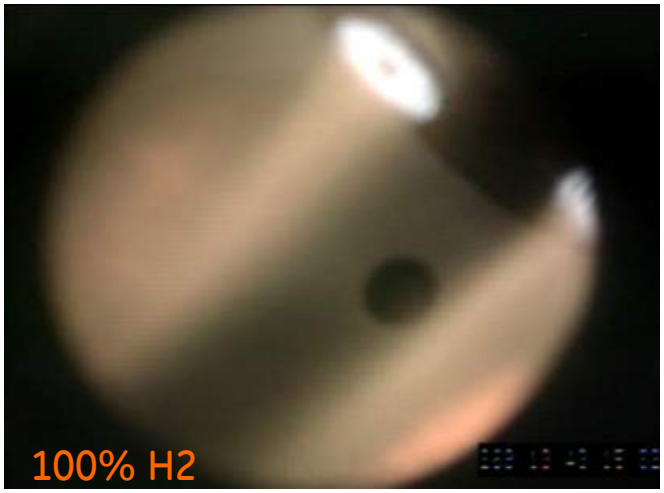


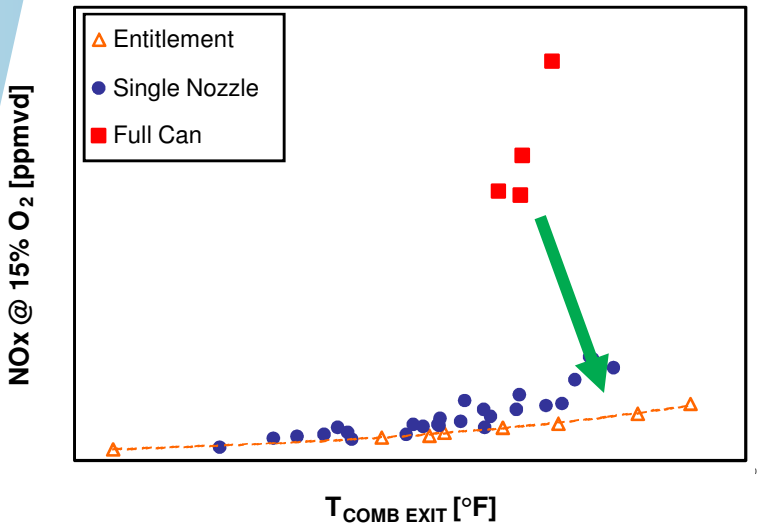
Physics-based predictive models



Single-Element Rig Testing

- Fundamentals
- Subcomponent testing
- Scale up
- Testing
- More work remains





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University Research – Combustion

- Measure turbulent burning velocities - of fuels at high pressure (with and without diluent)
- Develop and validate a kinetics mechanism - including NOx chemistry
- Develop analytical and/or computational predictive models - to study jet-in-crossflow flame stabilization
- Evaluate combustion dynamics

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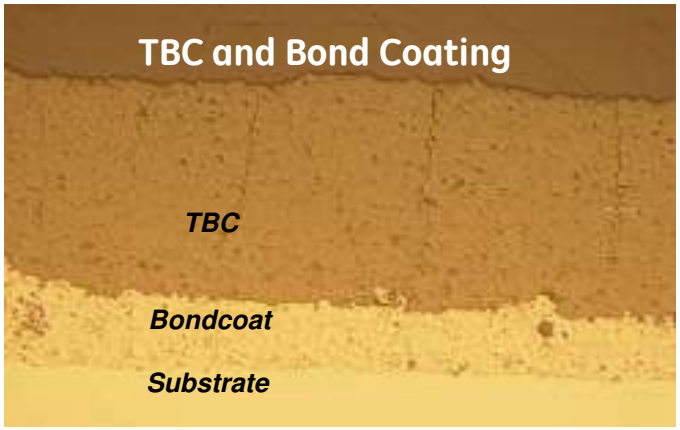
TBC Technology for Advanced H2 Gas Turbine

Thermal Barrier Coating Development Goals

- Improved stability, durability, and material properties
- Reduce thermal conductivity
- Validation of the environment



Challenges:

- Formation of Calcium Oxide-Magnesia-Alumina-Silica (CMAS)
- Thermal Resistance Degradation
- Spallation
- Progressive TBC Thinning
  - Erosion
  - CMAS-induced microspalling

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Thermal Barrier Coating Development

Technology Basics

- Candidate materials/coatings
- Development of tests

- Fundamental research

Component Advances

- Testing of Samples
- Application to components

Full Scale Validation

- Field testing of material coatings

Gas Turbine

- Higher material allowable temperatures
- Better efficiency, reduced active cooling

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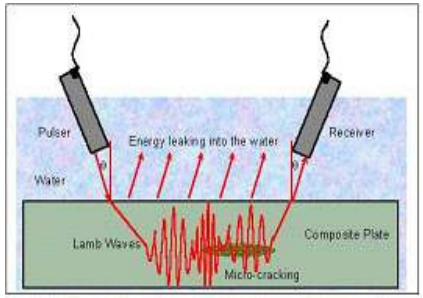
University Research – Materials

- Higher temperature TBC bond coat with improved rate of Thermally Grown Oxides (TGO)
- Approaches for TBC lifing models
- Improved corrosion resistance - to higher moisture content and deposits such as Na_2SO_4 and $CaSO_4$.
- Non Destructive Evaluation (NDE)

TBC and Bond Coating



Ultrasonic Testing (detects subsurface defects)

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Heat Transfer Technology for Advanced H2 Gas Turbine

Heat Transfer Improvement Goals

- Allow for higher firing temperature with reduced cooling

<u>Challenges:</u>

- Achieving higher film effectiveness – e.g. less cooling
- Design combination of cooling, material capability, thermal insulation

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Heat Transfer

Cooling Flow Reduction:

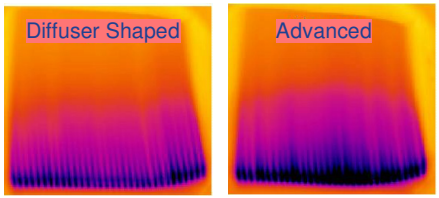
- Develop advanced cooling schemes

Leakage Flow Reduction:

- Decrease turbine parasitic leakages
- Improve seal designs,

Purge Flow Reduction:

- Decrease purge flows but keep disk cavities within max. temperatures
- Improve cavity rim sealing
- Optimize flow geometries to minimize hot gas ingestion and aerodynamic impact



Advance Film Cooling Hole Shapes

Improved TP/S1N Seal Parts

Rotating Cascade Rig

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Heat Transfer Cooling Improvements

Technology Basics

- Characterization
- Identify new concepts to improve cooling

- Fundamental Research

Component Validation

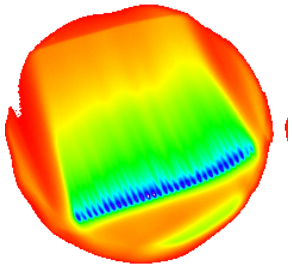
- Rig Testing
- Design itteration

Full Scale

- Validation on full scale components

Gas Turbine System

- Increased efficiency



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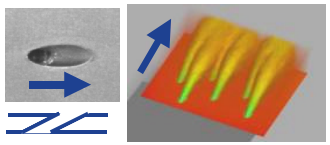
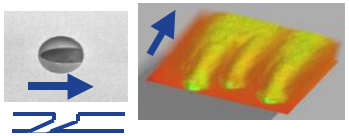
University Research – Heat Transfer

- Improved Cooling
  - airfoil surface cooling with film cooling or other approaches
  - internal surface cooling

- Improved Sealing/Reduced Purge Flow
  - Advanced concepts for rotor/stator sealing
  - Rotor rim geometry concepts to maintain/improve aero efficiency and minimizing ingestion



Round Holes



Crater Holes

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Program Summary

- GE's 1st integrated IGCC product being built – using 7F syngas turbine (based off of 7FB)
- Technology challenges for next generation of syngas/H2 gas turbines in combustion, cooling & heat transfer, materials
- DOE Programs with OEMs and with universities are focused on these challenges
- Keep going with all the great work you are doing

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Acknowledgements

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