UTSR 2012 Workshop

Mitsubishi Power Systems Americas, Inc.

October, 2012

Combustion Turbine Development Efforts
✓ Thermal Cycle Long Term Perspective (High efficiency)

✓ Japanese National Project (1,700 °C Turbine Inlet Temperature)

✓ Nuclear Combustion Turbine (Helium closed circuit)
  Pebble Bed Modular Reactor, PBMR

✓ Oxy-Fuel IGCC with Carbon Capture
  (Central Research Institute of Electric Power Industry, CREIPI)

✓ Fuel Cell based triple combined cycle
  (New Energy & Industrial Technology Development Organization, NEDO)
Mitsubishi Power Systems Americas

Established in April 2001

Blade and Vane Manufacturing Facility Orlando

HQ Lake Mary, FL

Turbine Manufacturing Facility, Savannah GA

Repair Facility Orlando

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MPSA’s 11 Year Growth

- **MPSA HQ, GT Repair Center**
- **Field Service Wind Turbine Blades**
- **CT Blade & Vane Manufacturing Center**
- **Savannah Combustor Manufacturing**
- **Gas Turbine Manufacturing Rotor Service Facility**

**Capital Investment Initiated**

- $40MM in 2001
- $91MM in 2007
- $133MM in 2009
- $225MM in 2011
- $550MM in 2006

**Employees**

- 7 Employees

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THERMAL CYCLE LONG TERM PERSPECTIVE
Early 2011
> 8,000 Actual Operating Hours

✓ Historical high fuel prices in Japan
✓ Commitment to reduce CO₂ emissions

1 on 1 GTGCC / 60 Hz
EFFICIENCY OF THERMAL POWER GENERATION

(1) GTCC (1,700 ºC)

(2) IGCC (Gasification)

(3) GTCC + SOFC (Hybrid Cycle)

Gross Efficiency [%]

(LHV %)


GTCC (LNG)

IGCC + SOFC

GTCC (1,700 ºC)

GTCC + SOFC (LNG)

USC (coal)
JAPANESE NATIONAL PROJECT (1,700°C)
JAPANESE NATIONAL PROJECT MOTIVATION

- Energy security:
  Most of the energy resources in Japan are imported

- Global Warming:
  Kyoto Protocol target = 6% reduction of CO2 emission

- Combined Cycle Power Plant:
  Improved Performance (60% → 62-65% LHV)

- Turbine Inlet Temperature:
  Higher (1500°C → 1700°C)
**Japanese National Project Scope**

### Exhaust Gas Recirculation
- **Without EGR**
- **With EGR**
  - Low O2

### High Efficiency Compressor / Turbine
- Multi Stage Analysis
- Higher Loading
- End Wall Treatment
- Advanced 3D Airfoil

### High Efficiency Cooling
- Steam/Air Hybrid Cooling
- Shroud
- Turbulator

### Advanced TBC
- **Conventional TBC**
- **Advanced TBC**

### Advanced Super Alloy
- Better than MGA1400DS
- Creep Strength: 100°C Higher with Same strength
- Anti Oxidation: 100°C Higher Limit
- Thermal fatigue: 50°C Higher with Same strength
Part of the Exhaust Gas from HRSG branches out and is mixed with fresh air and introduced to compressor inlet.

Without EGR

With EGR ratio 35%

Temperature (CFD)

Plant image of GTCC with EGR
Pebble Bed Modular Reactor
OXY-FUEL IGCC WITH CCS
The plant will capture 90% of the CO2 and transport is to a nearby oil field (EOR and sequestration).

- 400MW plant operating flexibly to increase generation of fertilizer during low electricity demand.
✓ Oxy-fuel system and semi-closed combustion turbine system.
✓ Simplified CO₂ removal and Capture System without Shift Reactor.

O₂/CO₂ Blown Gasification

Dry Gas clean-up under high CO concentration

O₂/CO₂ Firing Combustor

Central Research Institute of Electric Power Industry
FC B A S E D T R I P L E C O M B I N E D C Y C L E
**NEDO 200 kW SOFC MGT Combined Cycle**

**Project Results (2004 ~ 2009)**

<table>
<thead>
<tr>
<th></th>
<th>Target</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Systems</strong></td>
<td>200kW Class</td>
<td>Power Output</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SOFC 204kW-DC (188kW-AC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MGT 41kW-AC</td>
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<tr>
<td></td>
<td></td>
<td>Total 229kW-AC</td>
</tr>
<tr>
<td><strong>Electrical Efficiency</strong></td>
<td>&gt; 50%</td>
<td>52.1%-Net AC as LHV</td>
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**250 kW SOFC MGT Combined Cycle**

**Spec Plan for Demonstration System**
Capacity: 250kW class (Net)
Efficiency: 55% over (LHV/Net)
Total Heat Efficiency: 73% over (Hot water)
Fuel: City gas
Footprint: 14m × 5m = 70m²
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THANKS FOR YOUR ATTENTION