Development of Residential PEFC Cogeneration System in Osaka Gas

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1. Concept & Background of Residential PEFC Cogeneration System

2. Elemental Development of Residential PEFC Cogeneration System
   - Cell Stack Evaluation
   - Fuel Processor
   - Heat Recovery System

3. Development of Integrated PEFC Cogeneration System
Gas Engine Cogeneration System for Residential Application “ECOWILL”

<table>
<thead>
<tr>
<th></th>
<th>Gas engine System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Power</td>
<td>1 kW</td>
</tr>
<tr>
<td>Heat Output</td>
<td>3.25 kW</td>
</tr>
<tr>
<td>Electric Efficiency</td>
<td>20% (LHV)</td>
</tr>
<tr>
<td>Thermal Efficiency</td>
<td>65% (LHV)</td>
</tr>
<tr>
<td>Dimensions (mm)</td>
<td>D380 × W580 × H880</td>
</tr>
<tr>
<td>Durability</td>
<td>20,000 hours or 10 years</td>
</tr>
</tbody>
</table>

Osaka Gas has created market for residential cogeneration system
Concept of Residential Cogeneration System

Commercial Power Line

Electric Power

PEFC / GE System

City Gas

Heat Recovery System

Back-up Boiler

Air Conditioner

Light

Hot Water

Floor Heating

Shower

Bath

TV
Demand of a Standard Japanese Household

**Electric Power Demand**
- Annual Demand: 5,576kWh

**Hot Water Demand**
- Annual Demand: 6,060kWh

The Source: Surveyed by Institute of Research & Innovation in 1998

Total electric power demand is almost equal to that of hot water

Fit for PEFC Cogeneration System
## Targeting Specifications for Commercial Units

<table>
<thead>
<tr>
<th></th>
<th>700, 750 W</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rated Power</strong></td>
<td>700, 750 W</td>
</tr>
<tr>
<td><strong>Turn Down (W)</strong></td>
<td>250 / 500 / 700, 750</td>
</tr>
<tr>
<td><strong>Electric Eff. (HHV%)</strong></td>
<td>&gt;27.0 / &gt;30.5 / &gt;31.5</td>
</tr>
<tr>
<td></td>
<td>(@250W @500W @700,750W)</td>
</tr>
<tr>
<td><strong>Heat Recovery Eff. (HHV%)</strong></td>
<td>&gt;23.0 / &gt;34.0 / &gt;39.0</td>
</tr>
<tr>
<td></td>
<td>(@250W @500W @700,750W)</td>
</tr>
<tr>
<td><strong>Operation Mode</strong></td>
<td>Continuous (Start&amp;Stop :Summer Season)</td>
</tr>
<tr>
<td><strong>Durability</strong></td>
<td>10 years</td>
</tr>
</tbody>
</table>
System Advantage

For Environment (Comparison with Conventional system)
- Reduction of Primary Energy Consumption; 20%
- Reduction of CO₂ Emission; 30%
- Reduction of NOₓ Emission; 70%

For Consumer Benefit
Annual Savings of Energy Cost
 ; JPY 50,000 ~ 60,000 ( EUR 360 ~ 430 )
 = Total Annual Utility Costs 20% Saved

Target Sales Price
JPY 600,000 ( EUR 4,300 )

Allowable Cost Increase
; JPY 150,000 ~ 300,000 ( EUR 1,100 ~ 2,100 )

Comparison with Conventional System (=Central Heating Boiler)

... Payout ; 3 ~ 5 years

In the case of PEFC installation at the single-family house (Floor Area; 150m²)
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The Evaluation Study of PEFC Cell

Cell Durability Target

Transportation Application ; 5,000 hrs
Stationary Application ; 90,000 hrs

- Cell Durability is the most important factor
- No cell durability data was available

Evaluation study of PEFC single cells started in 1998

Durability Test under Various Conditions

Evaluation of Single cells
- Using 37 Apparatuses
- Cumulative Operation Time : 1,500,000 hrs
More than 40,000 h durability was verified
Characteristics of Fuel Processor

For Stationary Application:
Long durability & low manufacturing cost are most important

Catalysts;
50,000hrs durability was already verified in PAFC systems in 1998

Fuel Processor for Residential PEFC system

- Plate-shape Elements & Integrated in one Package
- High Thermal Efficiency > 82% (HHV)
- Low CO Concentration < 1 ppm (initial)
- Long Durability > 90,000 hours

750W - class Fuel Processor

No catalyst exchange including Desulfurizer

Cost Reduction Capability at Mass Production Stages

Shipped for 330 units For Domestic and Overseas companies
Start & Stop Endurance Test of FPS

Stable performance for more than

- 2,200 SS-times (Start & Stop test)
- 28,000 hours (Continuous Durability test)
Heat Recovery System

Running Efficiently for Any Residents, All Seasons
by Self-Learning Control Software

1. Accumulate Historical Data
   (Electric & Heat Demand)

2. Predict Demand
   (Electric & Heat Demand of Next Day)

3. Determine the Operation Mode
   (Output Power etc.)

Self-Learning Control can enhance energy saving ratio up to 4 points

Compact Size
D440×W750×T1900mm
Suitable for Small Residential Space in Japan

Shipped for 7 Companies/ 400 Units

Storage Tank ; 200L
Self-Learning Control Software
Back-up Boiler
Remote Controller
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Progress in PEFC Cogeneration System Development

Electrical efficiency over 31.5% (Max 33%), even at minimum load over 27%

Target system performance has been achieved by 2004
Schedule for PEFC Technology Development

**Development Phase**

**1999**
- Basic Performance Verification
- System Design Establishment

**2002**
- Electric Efficiency Achieved in 2002
- Joint Development with Promising Manufacturers

**2003**
- System Performance Verified in 2004

**2005**
- MTBF < 300hr
- Durability <10,000hr

**Integrated System Development**

Designed for Performance, Reliability & Durability
Field Testing at Real Residence

To Evaluate Energy Savings, System Reliability & Durability

Field Testing at Real Customers’ Houses (more than 85 units)

SANYO Electric ; 750W

TOSHIBA FCP ; 700W

Verified

Total primary energy consumption was saved more than 15%
**Durability & Reliability of Integrated PEFC Cogeneration System**

**System Durability**

- **Cell Degradation Rate**
  - $< 1 \text{mV/1000h}$

**System Reliability**

- **MTBF**
  - $< 300$ hrs in 2004
  - $> 3,000$ hrs in 2005

**System Operation**

- $> 10,000$ hrs

**Satisfied Requirements simultaneously for System Performance, Reliability & Durability**

- Basic system design was established in 2005
Schedule for PEFC Technology Development

- **Development Phase**
  - 1999: Basic Performance Verification
  - 2002: System Design Establishment
  - 2003: Electric Efficiency Achieved in 2002
  - 2004: System Performance Achieved in 2004
  - 2005: Basic System Design Established in 2005
  - 2007: Cost Reduction
  - 2008: Joint Development with promising manufacturers
  - 2008: System Cost Reduction

- **Integrated System Development**
  - 1999: Joint Development with promising manufacturers

- **Target of Commercialization**
  - 2009: System Performance Achieved in 2004
Conclusions

◊ Osaka Gas has been developing the residential PEFC cogeneration system with the core technologies

- Demonstrated Cell Durability over 40,000hrs
- Developed Durable & Low Cost Fuel Processor
- Developed Compact & Efficient Heat Recovery System, which Fits for Any Seasons & Residents with Self-Learning Control Software
- The system performance, reliability & durability has been demonstrated through field testing

**Basic system design was established in 2005**

◊ Collaborating with PEFC manufacturers, Osaka Gas is exerting all efforts

**To reduce system cost with satisfied reliability for the commercialization in 2008**