Compact and Efficient On-site Reformers for Hydrogen Refueling Stations

Japan-Norway Energy Science Week 2015
Tokyo, Japan, 27/28th May 2015

Retsu Hayashida
MITSUBISHI KAKOKI KAISHA, LTD.
http://www.kakoki.co.jp/
I. MKK’S HYDROGEN GENERATION TECHNOLOGY

II. B-DASH PROJECT
Company Overview

1. Company Name : Mitsubishi Kakoki Kaisha Ltd.
2. Head Office : 2-1 Ohkawa-cho, Kawasaki, Kanagawa
3. Founded : 1935
5. Annual Sales : ¥26,025 mil. (March, 2014)
6. Employees : 559 (March, 2014)

7. Principal business
Engineering, procurement and construction job for a wide range of industrial and chemical plants and environmental control facilities. In addition to plant business, manufacture and sales of many kinds of industrial machineries and equipments.
MKK Hydrogen Plant with a Wealth of Experience

1960

1990

2000

2010

1963 Large-Scale Hydrogen Plant

1996 Medium-Scale Hydrogen Plant

Small-Scale On-Site Type Hydrogen Generator

1999 TM Type

2005

2012
Mitsubishi Hydrogen Generator

Total Delivery: 129 units

Small On-site
50,100,200,300Nm³/h

Medium - Scale
50,100,200,300Nm³/h

Large - Scale
1,000 ~ 50,000Nm³/h

65 units (ICI type)

* MKK built the first steam reformer in Japan.
* MKK has the biggest delivery record in Japan.
* For Oil-Refining, Petrochemical, City Gas and other industries
* Photo: The Newest Hydrogen-Generator Model (PSA-type)

17 units (TOPSOE type)

* Adopts New Type Reforming Furnace suitable for Medium-Scale Users
* For treatment of Glass, Optical Fiber, Metal, etc.
* Photo: Hydrogen generator for Stainless Steel Bright Annealing

47 units - Hydrogen Station: 12 units -
(TM, HyGeia, HyGeia-A type)

* For Metal, Semiconductor, Hydrogen Refueling Station, etc.

**Adopts New Type Reforming Furnace suitable for Medium-Scale Users**
* For treatment of Glass, Optical Fiber, Metal, etc.
* Photo: Hydrogen generator for Stainless Steel Bright Annealing
* Photo: The Newest Hydrogen-Generator Model (PSA-type)
Steam-Methane Reforming Technology

Hydrogen Production Method

Desulfurization: \( R-S+H_2 \rightarrow R+H_2S \)

(Hydrodesulfurization) \( H_2S+ZnO \rightarrow ZnS+H_2O \)

Steam Reforming: \( C_nH_m+nH_2O \rightarrow nCO+(n+m/2)H_2 \)

\[ CO+3H_2 \leftrightarrow CH_4+H_2O \]

Shift reaction: \( CO+H_2O \leftrightarrow CO_2+H_2 \)

Purification: Adsorption (PSA)

Wet Scrubbing (Amine Absorption)

Membrane Separation
Process Flow of Hydrogen Generator

Feedstock (City gas or LPG) → Compressor → Preheater

Compressor

Preheater

Heater

Reformer

Shift Reactor

PSA

Hydrogen ≥ 99.999%
Double tube type reformer

- Fuel consumption reduce
- Heat Efficiency Upgrade

Diagram showing the process:
- Feedstock
- Reformate
- Catalyst
1. Compact Design & Easy Maintenance
The Plant is designed for Compact and Low operation pressure (Less than 1MPa)

2. High Efficiency
High efficiency accomplish Energy Conservation and Low H2 Production Cost

3. Easy Operability
Full Automatic operation is from Start-up to Hydrogen Supply.
HyGeia-A is developed for commercial onsite HRS

1. Improvement of reform. efficiency
   - Process study
   - Low S/C
   - Optimization of Heat balance

2. Compact
   - Reduction of catalyst loading
   - Re-design of reformer and heat exchanger

3. Low Cost
   - Minimize of material cost by compactification
   - Process simplification
# Small On-site Hydrogen Production Plant:

## Specification comparison

<table>
<thead>
<tr>
<th>Type</th>
<th>TM</th>
<th>HyGeia</th>
<th>HyGeia-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEEDSTOCK</td>
<td>13A City gas, LPG*1)</td>
<td>13A City gas, LPG</td>
<td>13A City gas, LPG</td>
</tr>
<tr>
<td>Capacity</td>
<td>40,50,100,200</td>
<td>50,100,200</td>
<td>300</td>
</tr>
<tr>
<td>Footprint</td>
<td>50Nm3/h: 18m2</td>
<td>50Nm3/h: 11m2 200Nm3/h: 38m2</td>
<td>300Nm3/h: 24m2</td>
</tr>
<tr>
<td>Reforming Efficiency</td>
<td>59</td>
<td>77</td>
<td>82.5*2)</td>
</tr>
<tr>
<td>NOTE</td>
<td>*1) Ex. Naphtha, Kerosene</td>
<td></td>
<td>*2) 75Nm3/h develop type</td>
</tr>
</tbody>
</table>

*1) Ex. Naphtha, Kerosene
*2) 75Nm3/h develop type
Unit Flow of Hydrogen Refueling Station

OnSite HRS
CITY GAS
LPG
FEEDSTOCK

OffSite HRS
Large Scale H2 Plant

Hydrogen Generator

H2 Storage Vessel

Hydrogen Compressor

H2 Dispenser

FuelCellVehicle

FuelCellBus
HyGeia & HyGeia-A for Hydrogen Stations
/ Constructed from 2011 to 2013

Haneda Hydrogen Station
JHFC / Tokyo Gas Co., LTD

CO₂ capture PSA and CO₂ liquefaction unit is added for usual station.

City Gas Reforming
Capacity: 50Nm³/Hr
Constructed 2011

Toyota Hydrogen Station
HySUT / Toho Gas Co., LTD

City Gas Reforming
Capacity: 100Nm³/Hr
Constructed 2013

Kaminokura Hydrogen Station
HySUT / JX Nippon Oil & Energy

LPG Reforming
Capacity: 150Nm³/Hr
Constructed 2013
MKK’s Hydrogen Refueling Stations

JX Nippon Oil & Energy
Yokohama Asahi Hydrogen Station

Idemitsu Kosan
Hadano Hydrogen Station

Idemitsu Kosan
Ichihara Hydrogen Station

Constructed in FY2014:
6 stations (on-site:2, off-site:4)
Toyota Ecoful HRS

MKK

100Nm³/h

H2 from NG
Senju HRS

MKK: 75Nm³/h H2 from NG
Kaminokura HRS

MKK: HyGeia
150Nm³/h
H2 from LPG
Hydrogen Stations
II. B-Dash Project

Utilization of Biogas from Wastewater Treatment Plant in Japan

- Heat of Methane Fermentation Plant: 94,438
- Incineration: 44,470
- Electric power generation: 42,104
- Sludge drying: 6,341
- Air conditioning: 2,592
- Others: 6,462

Total Biogas: 196,407

Utilized Biogas: 196,407 (71%)

Unutilized Biogas: 79,844 (29%)

⇒ FCV ≥ 1.5 million cars/year

Source: Database of Sludge Utilization (2002.3.31)
1. Background of the demonstration

1) The digestion gas is used for the gas generation and the warming of digestion tank, but approximately 30% are not used effectively.
2) Hydrogen production from biogas is CO2 free.
3) Biogas is the energy of local production for local consumption.
4) The demonstration of the hydrogen station using biogas is the first time in Japan.

2. The demonstration plant

<table>
<thead>
<tr>
<th>construction costs</th>
<th>1,378</th>
<th>Million Yen</th>
</tr>
</thead>
<tbody>
<tr>
<td>maintenance costs</td>
<td>66.5</td>
<td>Million Yen/Year</td>
</tr>
<tr>
<td>years of depreciation</td>
<td>12</td>
<td>Year</td>
</tr>
<tr>
<td>energy creation</td>
<td>484,038</td>
<td>MJ/Year</td>
</tr>
</tbody>
</table>
II. B-Dash Project

- Pretreatment
- Gas tank
- Digestion tank
- Siloxane Removing
- Compressor

2400Nm³/D
CH₄: 60%

1473Nm³/D
CH₄: 92%

3302Nm³/D
H₂: 99.999%

- Membrane
- Hydrogen generator

- CO₂ recovery facility (CO₂: 90%)

- Hydrogen station
- FCV

- H₂: 70MPa
- H₂: <45MPa
II. B-Dash Project: Prospects for the future

Offsite HRS

Onsite HRS

Greenhouse cultivation

Sewage Treatment Plant

Power supply of the emergency
II. B-Dash Project
Thank you for your attention!

This project was made possible by government assistance, and we hereby express our great appreciation to NEDO (New Energy and Industrial Technology Development Organization).

MITSUBISHI KAKOKI KAISHA, LTD.
http://www.kakoki.co.jp/