Introduction of KOGAS’s Activities on DME

September 8, 2010
DME4 in Stockholm, Sweden

Wonjun Cho, KOGAS

KOGAS R&D Division, DME Project
Content

○ DME Activities & Prospects in Korea
  ▶ Master Plan of DME Supply in KOREA
  ▶ DME Prospect (Market)
  ▶ Household & commercial use
  ▶ Transportation use
  ▶ Power generation use

○ KOGAS’s Activities on DME
  ▶ History of KOGAS DME Activities
  ▶ Development of KOGAS DME Process
  ▶ KOGAS DME Commercialization
  ▶ Global DME business of KOGAS

○ DME standard
DME Activities & Prospects in Korea
Government master plan of DME supply in Korea

(MKE, Ministry of Knowledge Economy)

'07. 7(1st Master plan), '09. 11(2nd Master plan)

Domestic Supply of DME fuel in 2013

- 1st Demonstration step('07~'09) : Study on the Quality Characteristics of DME-LPG Blending Fuel (Safety, Quality, Standard etc.) → Establishment of specific regulation
- 2nd Demonstration step('09~'11) : Test of Business Model of DME-LPG Blending Fuel (Supply DME-LPG blending fuel to domestic area)
- Promotion step('11~'13) : Oversea DME Project and Import DME (End of '13)
At present: Cosmetics, Spray propellant, Intermediate of agricultural chemical, LPG blending.

In future: Power generation, Transportation, Households & Commercial, etc.
(Korea will use it for households & commercial, transportation fuel in 2013)
- Household Use
  - Cooking appliance
  - Hot water boiler

- Industrial Use
  - Cooker for the restaurants
  - Industrial Boiler

- Chemical (Spray Propellant)
  - Aerosol propellant
  - Agriculture intermediates
DME-LPG blending test (KGS)

DME-LPG blending test facilities

Domestic DME-LPG Experimental System

Combustion Test

DME-LPG Test Facilities (Lab.)

Blending Test

Cylinder Test
Supply of DME-LPG blending (KOGAS)

- Fuel system for DME-LPG blending
  - cooking gas stoves: DME 20~30wt% + LPG 70~80wt%,
  - LPG vehicles for field test: DME 5~10wt% + LPG 90~95wt%
- Fuel Station for the filling of 100% DME and DME-LPG blending fuel
  - 100% DME Bus from the modification of diesel bus and LPG vehicles

DME-LPG blending & Filling System
100% DME Station & DME Bus
Features of DME vehicle from the modification of diesel vehicle

- Ultra-low emissions and low engine noise
- minor modification at low cost

KOGAS has developed the DME vehicles since 2005 (with KIER, SK).

- we already completed the key-technology for DME vehicles, and engine and a fuel supply systems successfully.
- 8,000 cc bus with 33 passenger
Less CO$_2$ emission than coal or oil fired power generation

Similar efficiency to gas fired power generation
- Generation efficiency in gas turbine: 39~40%

Demonstration is completed by KEPRI
- Retrofit fuel supply system
KOGAS’s Activities on DME
History of KOGAS DME Activities

- **DME Manufacturing Technology Development (KOGAS)**
  - LAB scale (‘00~’03)
  - 50Kg/day DME Pilot Plant (‘03~’05)
  - 10Ton/day DME Demo Plant (‘04~’09)
    - ’04~’06 : Safety standard study for DME fuel (KGSC)
    - ’04~’07 : Basic property study for DME-LPG blending fuel (KGSC)

- **DME Partnership Program**
  - ’04~’07 : Application technology development for DME fueled Power plant (KEPRI)
  - ’05~’08 : DME fueled diesel engine for Bus (KIER)

- **Demonstration and Model Business**
  - ’07~’10 : DME demonstration and model business (MOCIE)

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3,000 ton/ d DME production plant development from Small-medium size gas fields
**Technical properties**

- DME technology **using various feed stocks** like NG, CBM, Biogas, etc.
- Syngas process: **tri-reforming using 20% CO₂** included in gas field
- DME Process: application of efficient heat removal system of **fixed bed reactor with shell & tube**

**Development state**

- 2003: Pilot plant Construction and Operation (50~100 kg/d)
- 2008: Demo plant Construction and Operation (10 ton/d)

→ **Establishment of catalyst recipe and reactor design for commercial plant**
Development of core technology

- Syngas Catalyst
- Methanol Catalyst
- DME Catalyst

Engineering
- Optimum Process Simulation
- BEP Licensing
- Optimization technology

Catalyst
- Direct synthesis
- DME Purification
- CO₂ Recycle

Process Operation
- Tri-reformer
- Methanol reactor
- DME Synthesis Reactor

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<table>
<thead>
<tr>
<th>Process</th>
<th>Conditions</th>
<th>Catalyst</th>
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<tbody>
<tr>
<td>Desulfurization</td>
<td>350<del>400℃ 15</del>30atm</td>
<td>ZnO/ CaO</td>
</tr>
<tr>
<td>Pre-reforming</td>
<td>350<del>400℃ 15</del>30atm</td>
<td>Ni/ CuO/ MgO/ Al₂O₃</td>
</tr>
<tr>
<td>Tri-reforming</td>
<td>950<del>1050℃ 15</del>30atm</td>
<td>NiO-Mg/ Ce-ZrO₂/ Al₂O₃</td>
</tr>
<tr>
<td>DME Synthesis</td>
<td>230<del>280℃ 30</del>60atm</td>
<td>CuO/ ZnO/ Al₂O₃+ Additives</td>
</tr>
</tbody>
</table>
Gas field ➔ DME commercialization
※ DME import until 2013, Expected 1.5 million tons on 2015

- Establishment of commercial technology optimization
- Secured gas field (2010)
- Licensing of core technology

Gas field ➔ DME FPSO technology
Securing gas field of oversea, utilizing domestic shipbuilding company

CBM ➔ DME commercialization
※ Production of 10,000ton from coal and CBM

- Resource development cooperation projects in Mongolia ('09~'12)
- Secure resources from applied commercial technology
- Improvement of air pollution in Mongolia

- New growth green energy projects
- New growth businesses in KOGAS
- LPG and diesel alternative clean fuel supply

Domestic supply and market expansion
Demonstration step in 2009, Penetration from model distribution until 2011
Global DME business of KOGAS

Saudi Arabia
- 1000TPD (300,000TPY) DME Production MOU cooperation
  ('09.11) \(\rightarrow\) Import DME 300 KTPA in 2013
  - Natural gas price: 1.0~1.5$/MMBtu
  - Ready for Feasibility study, Economic analysis, etc

Mongolia
- Securing CBM (50~100 KM³), Construction and operation of
  10~20 KTPA DME Plant ('09.9 ~ '12.12)
  \(\rightarrow\) Supply of Ulaanbaatar and near area for the vehicle and household fuel

Vietnam
- DME business cooperation with state government of Thai Bihn in Vietnam ('10.3)
  \(\rightarrow\) Development of ocean gas field with Petro SAONAM (consortium)

Indonesia
- DME production capacity: 1.7 million tons per year ('2014)
  \(\rightarrow\) Use: DME-LPG blending fuel
  - Pertamina had been discussed with KOGAS and Daewoo Engineering ('09.11)

etc
- Myanmar, Oman, Australia etc
  - DME Production From CBM, Gas field (MEO Australia)
Battling Mongol’s air pollution with environment-friendly DME business utilizing CBM from rich coal resource

Improvement of Mongol’s Air Quality

Joint Research
- Joint R&D Center
- R&D for CBM Applications

Model Business
- DME Demo Plant
- Utilizing Nalaykha Coal mine

Commercial Plant
- Mid-Size DME Plant
- Large Coalfields

Business Start-up Foundation

Technology Demonstration

Profitable Business Model

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DME Project
With sufficient CBM feed gas (0.05~0.1 million M3 per day) available, DME plant of 10~20 thousand ton per year will be built.

- Use of CBM from Nalaykha coalfield near Ulaanbataar
- Project finance with a consortium by Korean and Mogolian companies

Supply of produced DME for transportation and household fuels
Historic Schedule

- '08. 12 : KOGAS DME Plant PR to Saudi Arabia, Oman etc
- '09. 11 : MOU with Saudi Arabia
- '10. 1 : KOGAS DME Technology Valuation and PFS (~‘10.4)
- '10. 3 : Korea-Saudi Working Committee (Incheon)
- '10. 7 : Agreement of Joint Study (Launching a Feasibility Study)

Main Contents of DME Business in Saudi Arabia

- Providing of KOGAS DME Technology
- Securing Utility (NG, Industrial Water, Area, Electricity etc) in Saudi Arabia
- Feasibility Study (Joint Study)
- Construction of 300,000ton/year DME Commercial Plant and Import (‘13)
K-DME Project in Saudi Arabia (II)

KOGAS DME
Plant
Core
Technology

Saudi
Arabia,
Al Jubail

DME Commercial Plant

- EPC Construction
- Trial Operation
- DME Production

KOGAS DME Plant Technology
- Complete KOGAS Demo Plant Technology
- Complete Basic Design of DME Commercial Plant

• Saudi Arabia applies the local conditions
  • Resource gas, Electricity, Industrial water, etc
  ⇒ DME production from overseas and import(‘13)
DME Business in Vietnam

Improvement of air pollution with environment-friendly DME business utilizing gas field

Improvement of Air Quality and Development of Gas Field in Vietnam

Gas Field
- Exploration & Production
- Development

Commercial Plant
- Construction
- Operation

Market
- DME-LPG Blending
- Diesel substitute

Business Start-up Foundation
Technology Demonstration
Business Model
With CO₂ rich natural gas of above 1.0 TCF, DME plant of 1 MM ton/year will be built and produced DME product.

Import to domestic fuels and export to others (Indonesia, Vietnam etc.)

- DME-LPG blending fuel & Diesel substitute
DME Standard
# Test method result of KOGAS DME

## 1. Test Method

<table>
<thead>
<tr>
<th>Sample</th>
<th>Phase</th>
<th>method</th>
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<tbody>
<tr>
<td>Syngas</td>
<td>Gas</td>
<td>On-line Gas Analyzer (ND-IR)</td>
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<tr>
<td>Product DME</td>
<td>Liquid</td>
<td>On-line Gas Chromatograph (TCD &amp; FID)</td>
</tr>
<tr>
<td>Impurity (Water Contents)</td>
<td>Gas &amp; Liquid</td>
<td>Karl-Fisher Coulometer</td>
</tr>
</tbody>
</table>

## 2. Analyzer

- On-line Gas Analyzer
- On-line Gas Chromatograph
- Karl-Fisher Coulometer

## 3. Test Results

<table>
<thead>
<tr>
<th>Sampling No.</th>
<th>Components</th>
<th>H2</th>
<th>CO</th>
<th>CH4</th>
<th>CO2</th>
<th>DME</th>
<th>MeOH</th>
<th>Total</th>
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<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; Operation</td>
<td>H2</td>
<td>0.0292</td>
<td>0.0008</td>
<td>0.0004</td>
<td>0.0002</td>
<td>99.4598</td>
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<tr>
<td></td>
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<td>2&lt;sup&gt;nd&lt;/sup&gt; Operation</td>
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<td>3&lt;sup&gt;rd&lt;/sup&gt; Operation</td>
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<tr>
<td>Average</td>
<td>H2</td>
<td>0.0097</td>
<td>0.0003</td>
<td>0.0001</td>
<td>0.0390</td>
<td>99.7296</td>
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</tbody>
</table>

Average DME Purity (mol%) : 99.7%
<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition (wt%)</td>
<td></td>
</tr>
<tr>
<td>Purity (wt%)</td>
<td>&gt;99.0</td>
</tr>
<tr>
<td>Methanol (wt%)</td>
<td>&lt;0.02</td>
</tr>
<tr>
<td>CO2 (wt%)</td>
<td>&lt;0.1</td>
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<tr>
<td>Methyl Formate (wt%)</td>
<td>&lt;0.01</td>
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<tr>
<td>Hydrocarbon (wt%)</td>
<td>&lt;0.5</td>
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<tr>
<td>Steam Pressure (40 °C, MPa)</td>
<td>&lt;1.05</td>
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<tr>
<td>Sulfur (wt ppm)</td>
<td>Not detected</td>
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<tr>
<td>Residue (mg/kg)</td>
<td>0.002</td>
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<tr>
<td>Copper Corrosion (40 °C, 1h)</td>
<td>Under 1 degree</td>
</tr>
<tr>
<td>Water (wt%)</td>
<td>&lt;1.0</td>
</tr>
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</table>
## DME-LPG Standard (KGS Code)

### LPG-DME Standard for household & commercial

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition (wt%)</td>
<td></td>
</tr>
<tr>
<td>LPG</td>
<td>Over 75.0</td>
</tr>
<tr>
<td>DME</td>
<td>Under 20.0</td>
</tr>
<tr>
<td>etc</td>
<td>Under 1.0</td>
</tr>
<tr>
<td>Steam Pressure (40°C, MPa)</td>
<td>Under 1.43</td>
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<tr>
<td>Sulfur (wt ppm)</td>
<td>Under 40</td>
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<tr>
<td>Residue (mg/kg)</td>
<td>Under 0.05</td>
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<tr>
<td>Copper Corrosion (40°C, 1h)</td>
<td>Under 1 degree</td>
</tr>
<tr>
<td>Water (wt%)</td>
<td>Under 0.04</td>
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</table>
## Distribution Model Business Regulation

- Specific Regulation for DME-LPG blending fuel (KGS AC211\textsuperscript{2009})
- To Check the Safety of the Equipment and Distribution Network in Korea
- To Supplement/Improve the Inadequate Problem
- Duration: 2009. 11 ~ 2011.11
- Start-up for DME-LPG Distribution: 2010. 8. 5

<table>
<thead>
<tr>
<th>Filling Station Company</th>
<th>Demonstration Field Tester</th>
<th>Site</th>
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<tbody>
<tr>
<td></td>
<td>Dong-Bang City Gas Industry</td>
<td>Kangreung City, Kangwon Prov.</td>
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<tr>
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<td>Youngjin Energy</td>
<td>Youngkwang City, Jeonnam Prov.</td>
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<td>Mokpo City Gas</td>
<td>Mokpo City, Jeonnam Prov.</td>
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<td></td>
<td>Chunil Gas</td>
<td>Pohang City, Kyungbuk Prov.</td>
</tr>
<tr>
<td>Manufacture Company</td>
<td>Korea Gas Corporation</td>
<td>Incheon</td>
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</table>