Gas Engine Power Generation
for CMM/VAM

Clean & High Efficiency Gas Engine Power Plant
MACH-30G
*** Stop the Green House Effect ***
Utilization of Coalmine Gas

MITSUBISHI HEAVY INDUSTRIES, LTD.
30th Oct.
2007
Road map for the presentation

- Introduction of MITSUBISHI MACH30G GAS ENGINE
- Utilization of CMM with MACH30G GAS ENGINE
What is MACH?

M(Mitsubishi)
A(Advanced Engine of)
C(Clean &)
H(High Efficiency)
## Principal Particular

<table>
<thead>
<tr>
<th>Engine Type/</th>
<th>V-type 4cycle Gas Engine (Pilot Ignition with Pre-chamber)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Cylinder</td>
<td>12</td>
</tr>
<tr>
<td>Cylinder Bore</td>
<td>mm</td>
</tr>
<tr>
<td>Stroke</td>
<td>mm</td>
</tr>
<tr>
<td>Speed</td>
<td>rpm</td>
</tr>
<tr>
<td>Gen. Output *1</td>
<td>kW</td>
</tr>
</tbody>
</table>

*1 when using Natural Gas or City Gas with Methane Number ≥65
KU SERIES SALES RECORD
IN THE WORLD

Total 404 units
2,056 MW

- 1 unit 7 MW Saudi Arabia
- 1 unit 4.4 MW Vietnam
- 5 units 20.5 MW Cambodia
- 2 units 7.2 MW South Korea
- 303 units 1520 MW Japan
- 4 units 19 MW Taiwan
- 6 units 25 MW Philippines
- 1 unit 4.2 MW Solomon Islands
- 2 units 6.8 MW Palau
- 27 units 152.6 MW Pakistan
- 1 unit 5 MW Sierra Leone
- 1 unit 5.6 MW Portugal
- 1 units 5.8 MW Egypt
- 11 units 82.9 MW Senegal
- 2 units 10 MW Turkey
- 2 units 10 MW Liberia
- 5 units 25 MW India
- 8 units 41.3 MW Indonesia
- 20 units 91.1 MW Thailand
- 2 units 6.8 MW Palau
**EXAMPLE OF MITSUBISHI GAS ENGINE ①**

<table>
<thead>
<tr>
<th>Client</th>
<th>Nippon Steel Corporation</th>
</tr>
</thead>
<tbody>
<tr>
<td>District</td>
<td>Chiba, Japan</td>
</tr>
<tr>
<td>Engine Type</td>
<td>18MACH-30G</td>
</tr>
<tr>
<td>Unit</td>
<td>10</td>
</tr>
<tr>
<td>Output</td>
<td>57,500kW</td>
</tr>
<tr>
<td>Delivery</td>
<td>2003,3</td>
</tr>
</tbody>
</table>
**EXAMPLE OF MITSUBISHI GAS ENGINE ②**

<table>
<thead>
<tr>
<th>Client</th>
<th>MHI Energy &amp; Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>District</td>
<td>Kanagawa, Japan</td>
</tr>
<tr>
<td>Engine Type</td>
<td>18MACH-30G</td>
</tr>
<tr>
<td>Unit</td>
<td>2</td>
</tr>
<tr>
<td>Output</td>
<td>11,500kW</td>
</tr>
<tr>
<td>Delivery</td>
<td>2002,10</td>
</tr>
</tbody>
</table>

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Feature of MACH Gas Engine

- **Lean burn (Base technology)**
  Pre-combustion chamber is equipped to main combustion chamber ➔ **Low NOx emission**

- **Pilot ignition**
  Fuel oil Pilot Ignition Valve is used for ignition source instead of Spark Plug
  ➔ **Make a stable combustion** & **Low NOx emission**

- **Fuel Gas Supply System**
  Fuel gas is supplied to each cylinder directly through the gas supply valves for them.
  ➔ **Higher response against load change**
Comparison of combustion between diesel engine and gas engine

**Diesel engine**
- Fuel injection valve
- Atomize

**Lean burn gas engine**
- Pilot fuel injection valve or spark plug
- Fuel-air mixture (gas+air)

<table>
<thead>
<tr>
<th>A/F Ratio 1</th>
<th>NOx level is high</th>
<th>Dust emission is high</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/F Ratio 2</td>
<td>NOx level is low</td>
<td>Dust emission is low</td>
</tr>
</tbody>
</table>

**Graph**
- NOx vs. A/F Ratio
- Peaks at A/F Ratio 1
- NOx level is high
- Dust emission is high

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Comparison between conventional gas engine (spark ignition) and new design (pilot injection)

Spark ignition

- Rich Mixture Gas
  - Increase NOx

- Lean Mixture Gas
  - Decrease NOx

Pilot injection

- Pilot oil
  - Injector (800J)
    - Decrease NOx

- Lean Mixture Gas
  - Stable Combustion

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Present Situation of Coalmine Gas

Methane Emission from world Coalmines \( \div 22.4 \text{ M ton/yr} \)

Same Green House Effect as CO\(_2\) of 470 M ton/yr

effect of CH\(_4\) is 21 times as CO\(_2\)

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Utilization Plan of CMM in China

<table>
<thead>
<tr>
<th></th>
<th>2005 (Actual result)</th>
<th>2010 (Target)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>15 billion m³</td>
<td>17.7 billion m³</td>
</tr>
<tr>
<td>Recovery</td>
<td>2.3 billion m³</td>
<td>10 billion m³</td>
</tr>
<tr>
<td>Utilization</td>
<td>1 billion m³</td>
<td>8.7 billion m³</td>
</tr>
</tbody>
</table>

The source: The 11th Five-year Plan for Coal Mine Production Safety

Utilization of CMM will lead good effect of not only [Reducing the exhaust energy] but also [Reducing CO2]

$\text{CH}_4$ 1 ton $= \text{CO}_2$ 21 ton

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CMM GAS POWER PLANT

UTILITIES IN COAL MINE

GAS ENGINE GENERATION PLANT

GRID

EXCESS ELECTRIC POWER

SUBSATATION

CONSUMER

VENTILATION FAN

VACUUME PUMP

RECOVERY METHANE

GAS HOLDER

30 < CH4 < 50%

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## Principal Particular for CMM Gas engine (Design Target)

| Engine Type |  V-type 4cycle Gas Engine  
|    (Pilot Ignition with Pre-chamber) |
|---|---|
| No. of Cylinder | 12 | 18 |
| Cylinder Bore | mm | 300 |
| Stroke | mm | 380 |
| Speed | rpm | 750 (Frequency 50Hz) |
| Gen. Output *1 | kW | 3450 | 5200 |

*1: CMM Gas Concentration of CH4 : More than 30%

The Gen. output is depend on the Gas condition and site condition

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Future Possibility to use VAM

Necessary to reduce Green House Gas further in future

Utilization of VAM (Ventilation Air Methane)

CMM
Methane $\equiv 30 \sim 50\%$

Turbo Charger

VAM
Methane $\equiv 0.3 \sim 0.7\%$

Engine (comb.chamber)

《Technical Problem》
Capability to burn Lean Mixture by mixing VAM

MACH-30G has high potential because of technical advantage of Lean Burn

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MACH-30G Technologies for Coalmine Gas

Problems with Conventional Engine

- Low Calorific Value
- Large Variation of Methane %

Unstable Ignition due to Low Ign. Energy

Combustion Variation

Abnormal Combustion

Knock with rich
Misfire with Lean

When mixing
VAM

Leaner Mixture

Solutions of MACH30G

Pilot Ignition
(High Ignition Energy)

Combustion Control

Lean Burn Technology &
Fuel Gas Direct Supply
system to cylinder

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Conclusion

We believe Mitsubishi MACH-30G Gas engine will contribute to stop the Green House Effect utilizing Coal Mine Gas.

Key Technology
Lean Burn Technology
Pilot Ignition
Combustion Control
Fuel Gas Direct Supply System to Cylinder

Reducing Exhaust Energy CO2
MACH-30G  (18MACH-30G)

Thank you