DME Vehicle Technical Standard Proposal in Japan including DME Filling Interface

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• DME vehicle structure and its Specific components
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History of DME vehicle technical development in Japan

- Starting in 1997, various research and development projects on DME vehicles for practical use were conducted with budgets of Ministry of Land, Infrastructure, Transportation and Tourism (MLIT) and Ministry of Economics, Trade and Industry (METI), in which 13 prototype DME vehicles were manufactured.
- In the project of “Next generation low emission vehicle development and its practical use” starting in 2002 with budget of MLIT, 6 DME vehicles (light, medium, and heavy-duty trucks and large-scale road sprinkler truck) were manufactured and tested by running on public road for practical use. During this period, lubrication of injection system, durability of seal materials, and so on have been well examined.
- In the final phase of this project, 2 medium-duty trucks for commercial use have run individually about 110,000km from 2009 to 2011.
  Conclusive technical requirements for securing safety and environmental conservation were summarized, and it was judged that DME vehicle could shift in a practical stage.

DME vehicle structure and its specific components

Structure of DME vehicle is basically same as that of diesel vehicle fueled with gas oil, except: Fuel system (Tank, Pump, Piping, Filling interface), Fuel injection system in engine (Supply pump, Common rail, Injector)
Proposal of DME Vehicle Technical Standard in Japan

- Targeted vehicle
- Standard of DME fuel for vehicle
- Odorant
- Fuel piping system
- Fuel tank
- Emission

DME vehicle technical standard drafting

- In order to manufacture DME vehicle in a practical stage, its technical standard shall be provided in the Road Transportation Vehicle Law under jurisdiction of MLIT in Japan.
- JDA (formerly, Bio-DME & DMEVPC) set up a study committee to draft a technical standard of DME vehicle in October, 2011.

Committee members:
- Prof. Norimasa IIDA, Keio University (chairman)
- academic experts
- delegates from related organizations and companies
- observers from MLIT and METI

- In the committee, DME vehicle technical standard was examined from various points of view, and its draft was settled in March, 2012 and submitted to MLIT and METI in April, 2012. It is now under review in both ministries.
DME Vehicle Technical Standardization in Japan

Various examinations were made on standards included in Road Transportation Vehicle Law and High Pressure gas Safety Law.

<table>
<thead>
<tr>
<th>Road Transportation Vehicle Law (MLIT)</th>
<th>High Pressure gas Safety Law (METI)</th>
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<tbody>
<tr>
<td>A.8 Engine</td>
<td>Filling equipment</td>
</tr>
<tr>
<td>applied without change (Fuel</td>
<td>Installation criteria</td>
</tr>
<tr>
<td>injection system to be modified</td>
<td>Requirement of safety measures</td>
</tr>
<tr>
<td>for DME characteristics)</td>
<td></td>
</tr>
<tr>
<td>A.17 High pressure gas Fuel System</td>
<td>Safety regulation (A.17)</td>
</tr>
<tr>
<td>detailed standard added to use DME</td>
<td>Fuel tank</td>
</tr>
<tr>
<td>A.31 Exhaust gas</td>
<td>Filling interface</td>
</tr>
<tr>
<td>PM&amp;NMHC are exempted from regulations.</td>
<td>Piping system</td>
</tr>
<tr>
<td></td>
<td>Pressurized filling system</td>
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<tr>
<td></td>
<td>Pressure balanced filling system</td>
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DME vehicle category targeted in technical standard drafting

In comparison with the diesel vehicle fueled with gas oil, the main advantages of the DME vehicle developed for practical use are summarized as follows:

1. As PM emission from DME vehicle is extremely little, PM measures as DPF are unnecessary.
2. NOx measures are easier.
3. Fuel consumption is similar.
4. CO₂ emission is less.

Considering these characteristics, an initial demand for DME vehicle is thought to be for the Commercial use vehicle of GVW3.5 ton or more. In this regard, the technical standard proposal has been determined to cover this vehicle category.
Standard of DME fuel for vehicle

Japan Industrial Standards (JIS) of DME fuel has been enacted in March, 2013. This standard is applied to DME manufacturer, of which the composition is shown below.

Standard of DME fuel for vehicle is based on it. As DME lacks the lubricity, the followings are added in the standard of DME fuel for vehicle.

(1) Addition of lubricity improver: for example, a lubricity improver of fatty acid is added with amount of 100-500mass ppm.

(2) Acid value of fuel after lubricity improver addition: 0.13mgKOH/g or less

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Standard value</th>
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</thead>
<tbody>
<tr>
<td>DME purity</td>
<td>mass %</td>
<td>99.5 or more</td>
</tr>
<tr>
<td>Methanol</td>
<td>mass %</td>
<td>0.050 or less</td>
</tr>
<tr>
<td>Water</td>
<td>mass %</td>
<td>0.030 or less</td>
</tr>
<tr>
<td>Hydrocarbon (C4 or less)</td>
<td>mass %</td>
<td>0.050 or less</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>mass %</td>
<td>0.10 or less</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>mass %</td>
<td>0.050 or less</td>
</tr>
<tr>
<td>Methyl formate</td>
<td>mass %</td>
<td>0.050 or less</td>
</tr>
<tr>
<td>Ethyl methyl ether</td>
<td>mass %</td>
<td>0.20 or less</td>
</tr>
<tr>
<td>Residue after evaporation</td>
<td>mass %</td>
<td>0.0070 or less</td>
</tr>
<tr>
<td>Total sulfur</td>
<td>mg/kg</td>
<td>3.0 or less</td>
</tr>
</tbody>
</table>

Odorant

Odorant addition is concluded unnecessary for DME fuel for vehicle by the following reasons:

1. DME has a peculiar ether smell, and the threshold of the human perception of the stench of DME vapor is 679ppm according to sensory tests conducted by the High-Pressure Gas Safety Institute of Japan. The lower explosion limit (LEL) of DME is 3.4%, and 1/5 of LEL is 6800ppm, and this value is 10 times higher than the above threshold. The person can perceive DME gas leakage in a safety concentration.

2. As the fuel tank and piping are installed outside under the vehicle body, leaking DME does not stay in the internal space of the vehicle.

3. As the commercial vehicle is handled by limited and specific persons, the safety can be secured by education on the gas smell, training on the safety and obligating the gas detector installation in the maintenance shop, etc.

4. The addition of the odorant containing sulfur compound is undesirable when DME is used for the fuel-cell vehicle in future.
Fuel piping system standard

For filling DME into the fuel tank of DME vehicle, the pressure balanced filling system is to be applied. Articles on this system are provided in a technical standard of DME vehicle, together with other articles for securing safety in the fuel piping system.

1. In order to equalize pressure among storage tank of DME filling station, main fuel tank and sub fuel tank of the vehicle, vapor phase part in each tank is connected by vapor line.

2. Filling interface: The following connecting ports are installed on the vehicle: (1)Liquid filling port (2)Vapor return line port to equalize pressure. (1) and (2) have a structure and size corresponding to the integrated nozzle of liquid filling line and vapor return line.

3. Regulations concerning safety of overfilling prevention valve: Pressure increase due to the water hammering phenomena, which could be generated when the overfilling prevention valve is closed, must cause neither damage nor leakage in the equipment and the piping parts in the upstream of the valve.

4. Installation of excess flow valve to prevent a gush leakage of DME from the fuel tank when the vapor phase piping breaks by any chance.

Countermeasure against Water hammering

Water hammering could happen when the fuel filling rate is as high as 80L/min and the overfilling prevention valve closes rapidly. Impact pressure possibly causes damage for the piping and equipment in the upstream of the valve. It is necessary to have measures to avoid such phenomena.
Fuel tank standard

As DME is categorized as a high-pressure gas in Japan, the technical standard of the fuel tank of DME vehicle was drafted as a technical standard of the High-pressure Gas Safety Law under METI.

1. Maximum filling pressure: 1.74MPa
   It is the same filling pressure as that of the fuel tank of the LPG vehicle. As the saturated vapor pressure of DME increases with temperature, it may become difficult especially in summer to keep an adequate filling flow rate with such a low filling pressure (1.08MPa) as it is for the DME tank of industrial use.

2. Hydrostatic test pressure: 2.9MPa

3. Material and structure: Steel plate for high pressure vessel (SG) and cylindrical welded structure.

4. Anti-corrosion treatment: (Outside) Rust prevention painting, (Inside) not necessary

5. Maximum filling volume of DME liquid: 85% of capacity of tank

6. Tank inspection cycle: Every six years within 20 years after its manufacturing, every two years beyond 20 years.

Emission standard

The emission from DME vehicle was examined comparatively with that from the diesel engine vehicle fueled with gas oil.

In comparison with the latest regulation for the diesel engine vehicle fueled with gas oil, the emission standard for the DME vehicle is drafted as follows;

<table>
<thead>
<tr>
<th>Regulated substance</th>
<th>Latest regulation of diesel vehicle fueled with gas oil</th>
<th>DME vehicle regulation (draft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>PM</td>
<td>0.01</td>
<td>exempted from regulation</td>
</tr>
<tr>
<td>NMHC</td>
<td>0.17</td>
<td>exempted from regulation</td>
</tr>
<tr>
<td>CO</td>
<td>2.22</td>
<td>2.22</td>
</tr>
</tbody>
</table>

PM: PM from DME vehicle is thought to come from engine oil and fuel additive, and the emission level is 0.01g/kWh or less without DPF, and of PM free level. NMHC: HC in the exhaust gas of DME vehicle is CH₄, and un-burnt DME, which has no adverse effect on the human health. The amount of the emission is so little.
Proposal of DME filling system and filling interface standard

• DME filling system for higher filling flow rate
• Standard of DME filling system & filling interface
  - Pressurized filling system
  - Pressure balanced filling system
  - Integrated nozzle for pressure balanced filling system
  - Analysis of DME vapor in DME vehicle fuel tank

• Standardization of DME filling interface

DME filling system for Higher filling flow rate

The fuel tank capacity of the targeted DME vehicles is as large as 250-600L. The fuel filling to DME vehicle should be conducted rapidly at about 80L/min in equivalent existing gas oil filling rate to the conventional diesel truck.

DME filling to DME vehicle is done through a series of systems from the storage tank to the fuel tank of the vehicle. In order to materialize such a rapid filling system, the following factors should be examined and optimized:

(1) Discharge pressure and flow rate of pump used in DME filling station.

(2) Flow rate/Pressure drop characteristics for piping system from pump to the filling equipment, for section from the inlet of the filling equipment to the joint coupling at the end of hose and for fuel receiving system of DME vehicle (piping from filling entrance to fuel tank).
DME filling system for Higher filling flow rate (cont.)

(3) Filling flow rate considering the above flow rate/pressure drop characteristics.

(4) Effect of outside temperature and DME vehicle fuel tank temperature on filling rate.

In Japan, DME vehicle manufacturers, Filling equipment manufacturers, and DME filling station constructors cooperatively examined the above factors and designed the optimum system.

They have established a pressure balanced filling system which can fill DME constantly at 80L/min without any influence of outside temperature and DME vehicle fuel tank temperature.

This new system is included in the standardization proposal of the DME filling system and filling interface.

Standard of DME filling system & filling interface

1. DME filling to DME vehicle is carried out by the following two filling systems.
   A. Pressurized filling system: for small vehicles having a small capacity fuel tank. (Conventional system used for LPG vehicle)
   B. Pressure balanced filling system: for medium-heavy duty trucks having a large-capacity fuel tank to be filled in a short time.

2. DME filling interface of liquid line is common to both pressure balanced filling system and pressurized filling system.

3. The dimensions of the integrated nozzle (liquid filling and vapor return lines) are standardized as the interface of the pressure balanced filling system.

4. The dimensions of liquid line interface of DME vehicles are different from those for LPG Vehicles to prevent miss-filling.
### Pressurized filling system

<table>
<thead>
<tr>
<th>Item</th>
<th>content</th>
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</table>
| **Filling method**    | ・DME from storage tank is pressurized by pump and filled through the filling equipment with built-in devices such as flow meter and hose to fuel tank of vehicle.  
  ・Residual DME vapor in fuel tank is pressurized and liquefied during filling. |
| **Issues**            | Filling flow rate drop happens caused by the pressure increase in fuel tank due to the temperature rise in the fuel tank.  
  ・During filling, the temperature in fuel tank increases due to liquefaction latent heat of DME vapor.  
  ・At the start of filling, the temperature in fuel tank is higher than that in storage tank because the return DME fuel in the fuel-feeding system may receive heat from engine and transfer it in fuel tank during vehicle running. |

### Pressure balanced filling system

<table>
<thead>
<tr>
<th>Item</th>
<th>content</th>
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</table>
| **Filling method**    | ・This system has a vapor line that connects the vapor phase part of the fuel tank and the storage tank in order to equalize pressure between the storage tank and the fuel tank from the beginning of the filling.  
  ・Constant flow rate can be kept even though the temperature of the fuel tank is higher than that in the storage tank. |
| **Filling nozzle**    | Integrated nozzle of Liquid filling line and Vapor return line           |
| **Filling measurement** | Accurate filling liquid volume measurement system counting return DME vapor volume through the vapor line. |
| **Safety at the end of filling** | Prevention system against water hammering phenomena occurred by rapid shut off of the over-filling prevention valve in the fuel tank |
Integrated nozzle
for Pressure balanced filling system

- Integrated nozzle was developed to achieve a simple operation of connection and disconnection for liquid filling and vapor return lines simultaneously.

Analysis of DME vapor in DME vehicle fuel tank

Purpose of examination
- A part of fuel returns from the engine to the fuel tank and its temperature rises with heat from the engine. DME in the vehicle fuel tank might be deteriorated for a longtime operation.
- In case of the pressure balanced filling system, DME vapor returning into the storage tank of DME filling station might contaminates the stored DME.

Sampling and analysis method
- 10L of gas sample was taken through the pressure equalizing valve of the main tank of the DME truck after running of 114,000km.
- Qualitative analysis was conducted by Gas chromatograph (GC) and Mass spectrograph (MS).

Results and evaluation
- Any components other than DME was not detected by the GC/MS analysis. Concordance rate is as high as 90%.
- There is no concern in quality degradation of DME in the storage tank of DME filling station by returning DME vapor from DME vehicle fuel tank.
Standardization of DME filling interface

Standardization of DME filling interface for DME vehicle is essentially important to introduce DME Vehicles in the market.

1. The standard of DME filling interface for DME vehicles to enable all DME vehicles from small to large to be filled safely and smoothly with DME fuel in all DME filling stations.

2. When the standard of DME filling interface for DME vehicles becomes common throughout the world, it will be easier to import and export DME vehicles and to promote eco-friendly DME vehicles internationally.

3. It is very important to set up the proper standard of DME filling interface for DME vehicles from the beginning of DME vehicle introduction for it is difficult to readjust the improper standard after it is once introduced.

Conclusion

• In order to promote a commercial DME vehicle manufacturing, DME Vehicle Technical Standard Proposal was drafted and submitted to MLIT, and now under review in MLIT.

• DME Vehicle Fuel Tank Regulations Proposal drafted was submitted to METI, and now under review in METI.

• DME filling interface for DME vehicle was examined and drafted as a standard, which is included in DME Vehicle Technical Standard Proposal.

• In order to promote an introduction of DME vehicle in the world, these standards should be internationally common as well as the standard of DME fuel for vehicle.

• JDA welcomes discussions on these standardization.
Thank you for your kind attention!