R & D for DME Vehicles infrastructure and Proposal for standardization

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## Background of R&D for DME Vehicles infrastructure

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<th>Areas</th>
<th>Current</th>
<th>Content of R&amp;D</th>
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<td>Filling system</td>
<td>• Liquefied gas filling method for vehicle is available in LPG filling equipment for small-size car (tank capacity = 50 to 100L) at filling speed of 20 to 30 L/min.</td>
<td>• Development of high-speed filling equipment for DME medium-heavy duty trucks at 80 L/min to be competitive against existing diesel oil filling speed</td>
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<td>DME filling stations</td>
<td>• Constructing DME filling station alongside major roads requires a significant site area (50m × 50m) under the current laws in Japan • Regulations for CNG stations are already relaxed</td>
<td>• Research on safety in the DME filling station to achieve relaxation of DME stations • Target is same regulations for CNG filling stations</td>
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The R&D for the above was executed under “R&D project for Regional innovation creation in 2008-2009” subsidized by Ministry of Economy, Trade, and Industry (METI)
Agenda

• Development of high-speed DME filling system

• Proposal for Standardization of interface between DME vehicle and DME filling equipment

• Research on safety in the DME filling station for the new technical standard
### Issues of existing technology for high-speed DME filling system

**Existing filling system: pressurized filling system  \textit{filling speed:30 L/min}**

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<th>Item</th>
<th>Issues</th>
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| **Filling method**            | **Cannot achieve 80 L/min of filling speed with pressurized filling system**  
• DME in the storage tank is pressurized by the pump and filled through the filling equipment to the fuel tank.  
• Filling speed is decreased because of the pressure increase in the fuel tank due to the temperature rise in the fuel tank.  
• One of the reasons of the temperature rise in the fuel tank is the liquefaction latent heat of DME vapor during filling.  
• Another reason is the back-flow of DME fuel to the fuel tank that may receive heat from the engine in the fuel-feeding system |
| **Safety at the end of filling** | **Countermeasures to prevent water hammering phenomena are needed for high-speed DME filling.**  
• At the end of filling, if the over-filling prevention valve in the fuel tank is shut off rapidly at 80 L/min, water hammering phenomena occurs. |
# Results of development of high-speed DME filling system

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<tr>
<th>Filling method</th>
<th>Pressure balanced filling system</th>
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<td>- Vapor line that connects the vapor phase part of the fuel tank and the storage tank in parallel with the liquid filling line. The storage tank and the fuel tank have an equal pressure thanks to connecting these two tanks from the beginning of filling.</td>
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<td>- Constant flow rate can be kept even though the temperature in the fuel tank is higher than that in the storage tank.</td>
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<tr>
<th>Ensuring safety at the end of filling</th>
<th>Development of water hammering prevention system by 2-step valves and level sensor</th>
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<tr>
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<td>- When the filling reaches 80% of tank capacity, 1-step stop valve is shut off by the signal of level sensor installed in fuel tank, and the filling speed is decreased.</td>
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<tr>
<th>Measurement system of the amount of the filling</th>
<th>Development of new measurement system for pressure balanced filling system</th>
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<tr>
<td></td>
<td>- Accurate filling volume measurement system constituted of measurement of returned DME gas volume in vapor return line, converting it to liquid amount, and compensation processing.</td>
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<th>Filling nozzle</th>
<th>Development of integrated nozzle of filling line and vapor return line</th>
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<td>- Simple operation of connection and disconnection for two lines simultaneously.</td>
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Performance results: Pressure balanced high-speed filling system

The goal (80 L/min) was achieved with pressure balanced filling system

Pressure balanced filling system

Constant 80L/min

Filling speed: constant at 80 L/min

Note: tank capacity is 135L
Pressure balanced filling system: Water hammering prevention system

• When the filling reaches a point of a level sensor installed in fuel tank, the signal is wire-transmitted to the DME filling equipment, 1-step stop valve in the filling equipment is shut off and the filling speed is decreased to prevent the water hammering.
• Without this system, 3.4MPa (about twice of design pressure 1.8MPa) of impact pressure occurs at the inlet pipe of fuel tank.
• With this system, no impact pressure occurred.

Pressure increase to max. 3.4MPa

Pressure transmitter range: 35MPa

No pressure increase

Pressure transmitter range: 2MPa

Installing water hammering prevention system

Avoidance of water hammer
Pressure balanced filling system: High accurate measurement system of the amount of filling

• Issue of measuring returned DME vapor volume:
  – In summer at a high temperature, temperature of fuel tank after running becomes well over that of DME storage tank at the filling station
  – At the above condition, when the vapor return line is connected to the fuel tank, DME vapor returns to the storage tank at a very high speed
  – In order to measure the volume of return saturated DME gas accurately under the above condition, measuring equipment with a wide measurement range and small pressure loss is required, but such measuring equipment is not available at present

• New measurement system:
  – To calculate the returned DME vapor volume by using actual filled liquid DME volume and pressures of fuel tank and storage tank before and after the filling

• Performance of new measurement system:
  – Filling volume measurement error is +0.47%
    • It meets Japanese legal requirement (within ±1%)
  – Without the compensation of returned DME vapor, the filling volume measurement error is +1.57%
Pressure balanced filling system:
Integrated nozzle for liquid filling and vapor return lines

- Develop integrated coupling of both liquid filling and vapor return lines

- The new design achieves lower weight of the nozzle while ensuring simple operation of connecting and disconnecting for liquid filling and vapor return lines simultaneously

Handle for opening & closing

Liquid filling line

Vapor return line

Handle for connection

Note: patent pending
Agenda

• Development of high-speed DME filling system

• Proposal for Standardization of interface between DME vehicle and DME filling equipment

• Research on safety in the DME filling station for the new technical standard
Standardization of the “Interface between DME vehicle and DME filling equipment” is an essentially important item to introduce DME Vehicles in the market upon the following viewpoints

1. It is thought to be an important necessity to set up the standardization of the DME filling interface for DME vehicles to enable all of DME vehicles, from small size to large ones, in all DME filling stations and in all seasons to be filled safely and smoothly with DME fuel.

2. It is considered to become easier to import and export DME vehicles when the standardization of the DME filling interface for DME vehicles becomes common throughout the world. As the result of such common standardization, it becomes easier to promote eco-friendly DME vehicles internationally.

3. It is required to set up different standardization of the DME filling interface for DME vehicles from that for LPG Vehicles to prevent miss-filling, because DME filling station system is similar to LPG filling station due to the same type of gas fuel.

4. It is very important to set up the proper standardization of the DME filling interface for DME vehicles from the beginning of the introduction of DME vehicles, as it is difficult to re-adjust the improper standardization after it is once installed.
Standardization of the DME filling interface for DME vehicles is considered based on the next framework in Japan

Framework of Standardization

1. DME fuel filling to DME vehicles is carried out by the following three filling systems.
   ① Pressure balanced filling system: for medium-heavy duty trucks having large-capacity fuel tanks
   ② Pressurized filling system: for small vehicles having small capacity fuel tanks
   ③ Pressurized filling system having a function of reducing the pressure of fuel tank: used in the private DME filling stations for vehicles with small-capacity fuel tanks

2. DME filling interface of liquid line is commonalized for 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 are different from that of LPG filling interface.
We, Bio-DME & DMEVPC planned this Special Event related to the Standardization of the DME filling interface for DME Vehicles

**Content of the Special Event**

1. Demonstration at Yokohama Liquefied Gas Terminal (YLT)
   - High-speed DME filling system for DME heavy duty trucks
   - New type of pressurized filling system having a function of reducing the pressure of fuel tank for small size DME Vehicles
   - The coupling nozzle with DME filling interface common to pressurized and pressure balanced filling system
   - High-speed DME filling for medium duty truck

2. Open-discussion about DME filling system and the standardization of the DME filling interface for DME vehicles at Hotel LiVEMAX in Yokohama

**Date:** Sat. Nov. 19. 1:00pm – 6:00pm

Welcome to everyone who is interested in this event.
Agenda

• Development of high-speed DME filling system

• Proposal for Standardization of interface between DME vehicle and DME filling equipment

• Research on safety in the DME filling station for the new technical standard
Background: regulations related to DME filling stations in Japan

• The High-pressure Gas Safety Law is a fundamental law for use and handling of any types of high-pressure gas
  – The law sets regulations for the installation of high-pressure gas equipment and plant including vehicle fuel filling stations
• Required distances between the filling equipment and borders of adjacent roads and premises are already shortened under clauses of the law specified for the following high-pressure gases for vehicle fuel:
  – LPG
  – CNG (compressed natural gas)
  – H2
• At present, DME is not considered as vehicle fuel under the law, therefore a very long safety distance (like other high-pressure gas equipments and plants etc.) is required for installing DME filling equipment stations
  – See the next slide
DME filling stations under the current High Pressure Gas Safety Law

• For high-speed DME filling equipments, at least 20m of safety distance from borders is required, which means the construction of the DME filling stations along major roads is unrealistic.

In addition, the current Fire Service Act does not allow the installation of DME filling equipment in the existing gas stations.
Target design of DME filling station by safety research

Equivalent to Compressed Natural Gas (CNG) filling station

- Shorter safety distance 6m from borders, 5m from roadway will enable construction of DME filling stations along major roads
- DME filling station located in the existing gas station, which could help accelerate building DME vehicles infrastructure
Research on the safety of DME filling stations

To support acceleration of construction of DME filling stations, the regulation specified for DME filling stations which is similar to those for LPG, CNG and H2 is needed to be established based upon the following research:

1. Experiments and simulations on the safety of DME filling stations
2. Risk assessments of anticipated accidents in DME filling stations
3. Studies of safety measures in DME filling stations
4. Studies of appropriate level of distances to ensure safety (target: equivalent to that for CNG filling stations)
Overview of experiments on the safety of DME filling stations

- Experiments in leaking DME from various sizes of pinhole apertures
  - Measurement of distribution of diffusive concentrations to determine distance to reach the lower explosive limit (LEL) and the 1 quarter concentration of the LEL
  - Measurement of flame reaching distance, blast pressure, radiation heat and heat flux to determine safety distance from the outside of the high-pressure gas facility to the boundary of the site
- Experiments of anticipated accidents
  - Measurement of flame length, blast pressure and radiation heat in case a DME vehicle accidentally started to move with filling hose still connected, the hose is broken, and the leaked DME is ignited
Overview of simulations on the safety of DME filling stations

Explosion of DME leaked from piping in a trench of a DME filling station

Distribution of DME diffusive concentration by leakage

Range of 1/4 concentration of LEL (1/4 LEL: 0.85vol%)

Range of target offset distance for fire: 4m

Range of 1/4 LEL concentration is within the target offset distance for fire

Assessment of blast wave pressure

Maximum distance to reach standard blast wave pressure value 2kPa at the safety distance is 4m.

Blast wave pressure at the target safety distance (6m) is less than 2 kPa.

Distribution of temperatures by explosion

Range of flame is within the range of target safety distance

Safety distance (target: 6m)

Site border

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Results

• It was confirmed that the safety in the DME filling station can be ensured by complying with the safety distances set for CNG filling stations.

• BioDME & DMEVPC formed the “Technical standard planning committee for DME filling stations for DME vehicles” on October of 2010 which:
  – Was composed of members such as academic experts, engineers of high-pressure gas equipments & the Equipment Industry Association, DME vehicle manufacturers, DME fuel manufacturers and so on
  – Deliberated and prepared the draft for a new Technical Standard for DME filling stations based upon the research

• The draft of new Technical Standard for DME filling stations was submitted to Nuclear and Industrial Safety Agency of METI on April 20, of 2011.
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