01 Methanol Fuel Applications - China
Methanol’s Evolving Global Demand

Methanol Demand vs Supply in 2017

Methanol Production/Import in China (mln tons)

- Production Capability
- Production
- Import

Source: CNFIA Statistics
• Methanol consumption increased to 69.5 MMTs in 2017

• Total Fuel Application (Direct Fuel, DME, MTBE) accounting for 25% of the total consumption in 2017

• Formaldehyde share dropped, MTBE share will be affected potential in 2020 when E10 promoted nationally.

• Methanol Direct Fuel in Industrial Boilers and Cookstoves increasingly contributed in the directive fuel blending

• Fuel blending is also suspected to contribute in “Others” in the official statistics

Source: CNFIA Statistics
China methanol production capability: 83.5 MMTs, mainly dedicated coal to methanol projects

- New NG stock feed methanol project suspended, coking gas limited by steel industry
- Advanced coal gasification and world scale methanol production

China: coal reserve rich country (115bln tons) with rare crude (2bln tons) and NG reserves

Increasing concerns of energy security, mainly crude, over 70% oversea import

methanol imports ~8 MMTs in recent years, in a similar assumption, China methanol oversea import only 11%

China Vehicle Population in 2018: 240 mln, consuming 100 MMTs gasoline and 140 MMTs diesel
Direct Fuel Blending (M15-M25)
Methanol Gasoline/Methanol Vehicle in China

**M15-M25**
- No Change on vehicle by blending low level methanol
- China uses M15
  - Estimated 7 million metric tons
- ~75% of cars built by international automakers

**Fuel and chemical Properties**
- Octane
- Heat value
- Ignition/flame temperature
- RVP
- Burning speed
- Solubility between each other
  - ....

**M85-M100**
- Dedicated vehicles (e.g. Geely)
- Use of SI technologies in light duty vehicles
- Both SI and CI for heavy duty vehicles
- Few changes needed to existing vehicle technologies at low cost
Methanol Gasoline-General Information

- China trailed M15 from 1980s
- First official promotion of M15 in Shanxi from 2002, late with Sinopec cooperation
- Shanxi’s experience to other provinces in China, including Shannxi, Zhejiang, Guizhou, Gansu, ect.
- Methanol blended for methanol gasoline around 2.5 MMTs by CAAEFA official statistics in recent years
- Certain amount of methanol officially in regular gasoline
**CHINA EXPERIENCE-National Standards**

**Fuel Based**
- The Additive of Methanol Gasoline for Vehicles
- Determination Method of Methanol Content in Methanol Gasoline for Motor Vehicles
- Methanol Gasoline (M85) for Motor Vehicles
- Fuel Methanol for Motor Vehicles
- Still on-hold: Methanol Gasoline (M15) for Motor Vehicles

**Infrastructure and Management Guideline by MIIT**
- Same for both M15 and M100
- Construction of Methanol Fuel Fueling Stations
- Guidelines for Safety Operation of Methanol Fuel

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<table>
<thead>
<tr>
<th>Standard</th>
<th>No.</th>
<th>Implemented Since</th>
</tr>
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<tbody>
<tr>
<td>The Additive of Methanol Gasoline for Vehicles</td>
<td>GB/T 34548-2017</td>
<td>2018</td>
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<tr>
<td>Determination Method of Methanol Content in Methanol Gasoline for Motor Vehicles</td>
<td>GB/T31776-2015</td>
<td>2015</td>
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<tr>
<td>Methanol Gasoline (M85) for Motor Vehicles</td>
<td>GB/T 23799-2009</td>
<td>2009</td>
</tr>
<tr>
<td>Fuel Methanol for Motor Vehicles</td>
<td>GB/T23510-2009</td>
<td>2009</td>
</tr>
</tbody>
</table>
### CHINA EXPERIENCE - Local Standards

#### Local standards available, province-wide promotion of methanol gasoline

![China Map](image)

#### Local standards available, pilot program on methanol vehicles initiated in selective cities/districts

<table>
<thead>
<tr>
<th>Province</th>
<th>Local Methanol Gasoline Standards</th>
<th>Implemented Since</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gansu</td>
<td>M15 + M30</td>
<td>2009</td>
</tr>
<tr>
<td>Guizhou</td>
<td>M15</td>
<td>2010</td>
</tr>
<tr>
<td>Hebei</td>
<td>M15 + M30</td>
<td>2010</td>
</tr>
<tr>
<td>Heilongjiang</td>
<td>M15</td>
<td>2005</td>
</tr>
<tr>
<td>Jiangsu</td>
<td>M45</td>
<td>2009</td>
</tr>
<tr>
<td>Liaoning</td>
<td>M15</td>
<td>2006</td>
</tr>
<tr>
<td>Shaanxi</td>
<td>M15 + M25</td>
<td>2004</td>
</tr>
<tr>
<td>Shandong</td>
<td>M15</td>
<td>2012</td>
</tr>
<tr>
<td>Shanghai</td>
<td>M100</td>
<td>2013</td>
</tr>
<tr>
<td>Shanxi</td>
<td>M5, M15, M85 + M100</td>
<td>2008</td>
</tr>
<tr>
<td>Sichuan</td>
<td>M10</td>
<td>2004</td>
</tr>
<tr>
<td>Xinjiang</td>
<td>M15 + M30</td>
<td>2007</td>
</tr>
<tr>
<td>Zhejiang</td>
<td>M15, M30 + M50</td>
<td>2009</td>
</tr>
<tr>
<td>Ningxia</td>
<td>M15 + M30</td>
<td>2014</td>
</tr>
</tbody>
</table>
Methanol Gasoline Infrastructure Achievements

- 50 methanol gasoline blending terminal centers completed/under construction in 15 different provinces
- Over 1.2 million metric tons (400 million gallons/1.5 billion liters) of annual methanol fuel blending capacity
- Total number of over 1200 refilling stations
- In 2013, 0.8 MMTs of M15 sold in Shanxi, accounting for 23% of the total gasoline market
M15 Emission Tests in China

- M15 emission test in Beijing Institute of Technology (BIT)

- Conventional Emission:
  - Methanol improving tailpipe emission of CO, HC and NOx

- For unconventional emissions:
  - NO increase of HCHO by introducing methanol
  - Significant reduction of BETX and PM
  - BETX (benzene, ethylbenzene, toluene, xylene)
  - PM major contributor to smog in cities and difficult to reduce, especially in numbers
Other Technology Concerns on M15

Metal Corrosion and nonmetal swelling

- Methanol corrosive to some metals, modern vehicles engineered to accommodate alcohol fuel like E10
- Proper corrosion inhibitor used in China
- Methanol small molecular structure swells the rubber and plastic components
- Modern vehicles can working with low level of alcohol gasoline
- China national standard of GB/T 24141 requiring rubber tubes in the fuel piping MUST accommodate oxygen-contained gasoline
- High level methanol fuel like M100, must use swelling resistant technology
- Swelling inhibitor may needed for old year model

Phase Separation, Vapor lock, injector block…

Corrosion Test of a Chinese M15 Inhibitor under US SAEJ1747 Standard

<table>
<thead>
<tr>
<th>Testing plate</th>
<th>Red copper</th>
<th>Steel</th>
<th>Stainless Steel</th>
<th>Cast aluminum</th>
<th>Zinc</th>
<th>Tin</th>
<th>Brass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight loss per surface unit (mg/cm²)</td>
<td>Max: 0.061</td>
<td>0.041</td>
<td>0.013</td>
<td>0.067</td>
<td>0.272</td>
<td>0.044</td>
<td>0.039</td>
</tr>
<tr>
<td>Min: 0.000</td>
<td>-0.047</td>
<td>-0.012</td>
<td>0.014</td>
<td>0.102</td>
<td>0.000</td>
<td>0.015</td>
<td>0.015</td>
</tr>
<tr>
<td>Average: 0.026</td>
<td>-0.011</td>
<td>0.001</td>
<td>0.027</td>
<td>0.208</td>
<td>0.019</td>
<td>0.023</td>
<td>0.023</td>
</tr>
</tbody>
</table>

US Standard Limits
- 0~0.070
- 0.050
- 0.020
- 0~0.080
- 0~0.350
- 0
- 0
- 0

Comparison Test on Regular Rubber Fuel Tube in Methanol Gasoline of 3 Different Ratios and Standard Gasoline

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Tube size before immersion</th>
<th>Tube size after 4 weeks of immersion</th>
<th>Swelling scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (mm)</td>
<td>Inner diameter</td>
<td>Outer diameter</td>
<td>Length (mm)</td>
</tr>
<tr>
<td>93rd gasoline</td>
<td>4.52</td>
<td>10.66</td>
<td>21.22</td>
</tr>
<tr>
<td>M10</td>
<td>4.58</td>
<td>10.5</td>
<td>20.6</td>
</tr>
<tr>
<td>M15</td>
<td>4.76</td>
<td>10.62</td>
<td>20.26</td>
</tr>
<tr>
<td>M30</td>
<td>4.52</td>
<td>10.5</td>
<td>20.7</td>
</tr>
</tbody>
</table>

NO Difference!
Direct Fuel Blending and Dedicated Vehicles (M100)
High Level Methanol Fuel Blending-General Information

- China R&D work from late 1980s with the US cooperation
- First official promotion of methanol vehicles using high level blends in 2000s in Shanxi
- National Pilot by Ministry Industry and Information Technology (MIIT) since 2012 in 5 regions with over 1,000 vehicles
- New Policy paper is introduced in 2019 for national promotion
- Roughly 100K retrofitted vehicles for M100 in China consuming over 1 MMTs of methanol each year
- OEMs Involved Geely Auto, FAW, Yu Tong, etc
MIIT Methanol Vehicle Pilot

- Over 1,000 vehicles received acceptance review
- Total pilot mileage over 184 million km
- The methanol fuel consumption over 24 kts.
- Health check to 1,199 people from a variety of occupations with potential methanol exposure like vehicle drivers & maintenance works, fueling station staff, operators in methanol fuel blending
- Taxi fuel cost saving around 30%
- Total number in operation over 7,000 now and projected to reach 15K-20K in 2019

### Methanol Vehicle Operation in China (by January 2019)

<table>
<thead>
<tr>
<th>Province</th>
<th>City</th>
<th>Vehicle Type</th>
<th>Vehicle No.</th>
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</thead>
<tbody>
<tr>
<td>Shanxi</td>
<td>Jinzhong</td>
<td>Taxi</td>
<td>260</td>
</tr>
<tr>
<td></td>
<td>Changzhi</td>
<td>HD Bus</td>
<td>96</td>
</tr>
<tr>
<td>Shanghai</td>
<td>Minhang</td>
<td>Taxi</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Xi’An</td>
<td>Taxi</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td>Baoji</td>
<td>Taxi</td>
<td>200</td>
</tr>
<tr>
<td></td>
<td>Yulin</td>
<td>Self-Dumping Truck</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Hanzhong</td>
<td>Taxi</td>
<td>20</td>
</tr>
<tr>
<td>Guizhou</td>
<td>Guiyang</td>
<td>Taxi</td>
<td>4776</td>
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<tr>
<td>Gansu</td>
<td>Lanzhou</td>
<td>Taxi</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>Pingliang</td>
<td>Taxi</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>7090</td>
</tr>
</tbody>
</table>
Environment Benefit for Methanol Vehicles

- Methanol improving tail pipe emission significantly
- Future Vehicles certified according to Euro 6 equivalent
- Other technology solution with same emission level of Euro 6, requiring higher cost after treatment like Urea Doping
- No formaldehyde increase, even below US standard

![Graph showing emission levels for different Euro standards](image)

CA6SH-ME4 HD SI M100 (GB17691-2005, Eqv. Euro 5, ESC) VS. China Emission Standards of Diesel Vehicle
Fueling Infrastructure for Methanol Vehicles

- 20 fueling infrastructures: 13 fixed stations and 7 skid mounted
- NO significant cost to change gasoline station to M100
- Promotional plan targeting of 35 by 2020 and 45 by 2019 in Cities of Guiyang and Xi An
- Market fuel price according to gasoline and NG prices
China M100 Vehicle OEMs

Geely Auto
- SI M100 with key components improved on corrosion, lubrication, fuel injection
- 14 M100 cars demonstration in Iceland
- HD bus and trucks under development
- Engine Calibration by MI member Fuel Injection Tech

FAW Truck and Yu Tong Bus
- SI M100 HD engine for HD trucks and buses produced by FAWJY

Tianjin University
- CI, Diesel Methanol Compound-Combustion (DMCC)
  HD trucks, marine and locomotives
  Applied to truck retrofitting
M100-Geely Dakar Racing 2019

Geely “methanol power”
M100-Geely Dakar Racing 2019

- GEELY AUTO SHELL LUBRICANT COOPER TIRE Team
- M100 Fuel used in the racing
- M100 engine was calibrated in Spain and tested in Middle East
- Methanol originated from Trinidad and Tobago
- Fuel Supply Supported by Geely’s car dealer in Peru
- Methanol quality instability discovered by Geely from color

WWW.METHANOL.ORG
Methanol Engine for Electricity and Heat

- Methanol engine can be used for electricity and CHP (combined heat and power)
- High efficiency achieved from optimized engine speed and exhaust heat recovery
- Even lower emission than road applications
- Distributed power and air-conditioning for remote areas and islands
- Engine size can be as large as 6MW, the same for Stena Germanica marine engine

A 4 cylinder engine SI for CHP in trial
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