Methanol Fuel Blending In China

Tim Chan – Enmore 14th International MeOH Week Nanjing, China 9 -10 July 2019
About Methanol Institute
History

• The Methanol Institute (MI) was established in 1989

• 29 years later, MI recognized as the trade association for the global methanol industry

• Facilitating methanol’s expansion from our Singapore headquarters and regional offices in Washington DC, Brussels, and Beijing
Members

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Methanol’s Evolving Global Demand

Methanol Demand vs Supply in 2018

Methanol Production/Import in China (mln tons)

Source: CNFIA Statistics
Fuel Application the Largest Downstream

• 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 might decrease 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: 84.32 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 scarce crude (2bln tons) and NG reserves

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

Methanol imports ~8 MMTs in recent years, 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**
- 7 MMT of methanol used for M15 blends in China
- ~75% of cars built by international automakers
- Under China’s new policy on methanol as a transport fuel, lower blends (M15 -25) are not encouraged

**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 trialed M15 from 1980s

• First official promotion of M15 in Shanxi from 2002, with Sinopec cooperation

• Shanxi’s experience shared with other provinces in China, including Shannxi, Zhejiang, Guizhou, Gansu, etc.

• 2.5 MMTs of methanol blended with gasoline by CAAEFA official statistics in recent years

• Low levels of methanol officially in regular gasoline
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

<table>
<thead>
<tr>
<th>Standard</th>
<th>No.</th>
<th>Implemented Since</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Additive of Methanol Gasoline for Vehicles</td>
<td>GB/T 34548-2017</td>
<td>2018</td>
</tr>
<tr>
<td>Determination Method of Methanol Content in Methanol Gasoline for Motor Vehicles</td>
<td>GB/T31776-2015</td>
<td>2015</td>
</tr>
<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>
Local standards available, province-wide promotion of methanol gasoline

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

### CHINA EXPERIENCE - Local Standards

<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 + M30</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 1,200 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)
• Methanol improves tailpipe emission of CO, HC and NOx

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

Metal Corrosion and nonmetal swelling

- Methanol is corrosive to some metals, modern vehicles engineered to accommodate alcohol fuel like E10
- Proper corrosion inhibitor used in China
- Methanol small molecular structure causes swelling of 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 be needed for old vehicle models

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 area 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>0.007</td>
<td>0.102</td>
<td>0.000</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>0.019</td>
<td></td>
</tr>
</tbody>
</table>

US Standard Limits

- Weight loss per surface area unit (mg/cm²)
  - Max: 0.070
  - Min: -0.050
  - Average: -0.020

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></td>
<td>Diameter (mm)</td>
<td>Diameter (mm)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inner diameter</td>
<td>Outer diameter</td>
<td>Length (mm)</td>
</tr>
<tr>
<td>93° 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>
</tr>
</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></td>
<td>Mini MPV</td>
<td>15</td>
</tr>
<tr>
<td>Shannxi</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>
</tr>
<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></td>
<td>Total</td>
<td>7090</td>
</tr>
</tbody>
</table>
Environmental Benefits of Methanol Vehicles

- Methanol improves tail pipe emissions 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

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 (~30,000 RMB)
- 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
- 300,000 units/year production capacity

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
China’s Policy for Methanol as a Transport Fuel

• Based on the positive results of the pilot, 8 ministries and agencies released a policy for methanol as a transportation fuel on 19 March 2019
  • To promote methanol vehicles among consumers
  • 5-year projection: **50,000 cars, trucks, and buses**
  • >500,000MT of methanol consumed/year
• Allows consumers free choice to purchase methanol fuelled vehicles
  • **32 models** certified by MIIT
  • Previously only opened to licensed operators under the pilot project
• Central government will not give subsidies but local governments can
  • Shanxi Province, Gui Zhou, and Xi An City giving subsidies (RMB 5,000/passenger vehicle and RMB 10,000/commercial vehicle)
  • MIIT studying how to involve methanol vehicles in **Double Credit Scheme** – will incentivise OEMs
M100-Geely Dakar Racing 2019

Geely “methanol power”
• 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
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 on trial
05 METHANOL AS A BOILER FUEL
Methanol Boiler Basics - Structure

Diagram showing the structure of a methanol boiler, including:
- Drum
- Combustion chamber
- Burner

Flowchart:
- Methanol storage tank
- High methanol tank/pump
- Methanol burner
- Methanol boiler
Methanol Boiler Basics – Applications and Construction Layout

- Widely used for heating and industrial stream, new built and replacing coal
- Capacity ranged from 1 to 20 t/h
- Fuel: 100% methanol to methanol blends with methanol content over 60% in vol.
- One steam ton capacity consuming 110 kg of methanol, industrial use can be long hours
- Estimated more than 1000 units, consuming over 2 MMTs methanol in 2017

Source: Methanol New Energy Applications in China: Boilers and Cook Stoves
**Methanol Boiler Economics**

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Methanol (Low Price)</th>
<th>Methanol (High Price)</th>
<th>NG (Low Price)</th>
<th>NG (High Price)</th>
<th>Diesel</th>
<th>Coal</th>
<th>Commerical and Industrial Electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Price (RMB)</td>
<td>1.8/kg</td>
<td>4/kg</td>
<td>2.2/m3</td>
<td>10/m3</td>
<td>5.5/kg</td>
<td>0.4/kg</td>
<td>0.9/kwh</td>
</tr>
<tr>
<td>Unit Price/0.1cal (RMB)</td>
<td>3.8</td>
<td>8.4</td>
<td>2.6</td>
<td>11.8</td>
<td>5.5</td>
<td>0.5</td>
<td>10</td>
</tr>
<tr>
<td>Thermal Efficiency</td>
<td>90%</td>
<td>90%</td>
<td>90%</td>
<td>90%</td>
<td>90%</td>
<td>55%</td>
<td>96%</td>
</tr>
<tr>
<td>Actual Economics (RMB/0.1 cal)</td>
<td>4.2</td>
<td>9.3</td>
<td>2.9</td>
<td>13.1</td>
<td>6.1</td>
<td>1.45</td>
<td>11</td>
</tr>
</tbody>
</table>

- Methanol Opex comparable to NG depending on regions, helped to fill the clean fuel gap in last winter when NG was short of supply
- Methanol as liquid fuel has superior Capex benefit to NG
- Diesel being eliminated due to its emissions despite its price dropping quickly
- Coal is 100% off the market in most cities of China
**Emission Tests in China**

- Methanol Fuel Blends: Jin Jing Da
- Neat Methanol: LinJing
- Methanol showing superior emission benefits to other hard fuels and diesel
- Methanol has no Sulphur and NOx emission is superior than NG boiler
- Methanol boiler easily fulfilling the latest Chinese emission standard even in Key Regions like Beijing, Shanghai etc.
Policy Initiative for Methanol Boilers


The Boiler Burner Authority on New Classification to include Methanol as Burner Fuel

- Burner Test Lab of China Special Equipment Inspection and Research Center
- Alcohol based fuel in liquid fuel category for boiler burners
- Standard will be in effective since 2018
- Original emission concentrations, designing specifications, etc.
CPCIF Group Standards for Methanol Boilers

Methanol Based Fuel Group Standards Under CPCIF

- CAAEFA leading a research group on two Group Standards under CPCIF
- More than 12 cooperative companies from China including boiler manufacturers, fuel suppliers, storage/tanker producers
- MI and MI member Methanex also contributed
- Anticipated to be effective in NOV of 2018

1. Methanol Based Fuel for Boilers

- Burner and fuel composition tests conducted by National Lab of Coal Clean Utilization in Shan Dong University
- Methanol Boiler Fuel is classified into MF50, MF75 and MF100

Important Note: The table referred here is the draft by 5th of June, 2018. Detailed specification numbers may be changed.
2. Technical requirements for storage and supply facilities of methanol based fuel for boilers

- Specifications in safe use and storage of fuel, on volume, safety distance, precautions, etc.
- Max. Storage capacity less than 150m³, less than 20m³ in the urban built-up area
- Skid Mounted storage allowed, which will facilitate promotion
- Safe distance based on above-ground/under-ground storage tank and different nature of buildings

---

<table>
<thead>
<tr>
<th>Building (structure)</th>
<th>Underground storage tank</th>
<th>Aboveground storage tank</th>
<th>Unloading (fuel supply) pump, the vent pipe opening and other buildings (structures) (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$V \leq 150m^3$</td>
<td>$V &gt; 20m^3$</td>
<td></td>
</tr>
<tr>
<td>Important public building</td>
<td>35</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>A place near open flame or spark</td>
<td>17.5</td>
<td>12.5</td>
<td>25</td>
</tr>
<tr>
<td>Protection category of coal buildings</td>
<td>14</td>
<td>11</td>
<td>20</td>
</tr>
<tr>
<td>Under Category I protection</td>
<td>11</td>
<td>8.5</td>
<td>16</td>
</tr>
<tr>
<td>Under Category II protection</td>
<td>8.5</td>
<td>7</td>
<td>12</td>
</tr>
</tbody>
</table>

Important Note: The table referred here is the draft by 5th of June, 2018. Detailed specification numbers may be changed.
Other Form of Methanol Burners – Furnaces and Kilns

• Using methanol burner for ceramic sintering, metal alloying, tobacco drying, etc.

• Better ceramic surface finish: less flaws, brighter color due to the clean exhaust gas from methanol

• Better energy efficiency reported: less air intake comparing to NG

• Regular safety incidents with LPG, making methanol more appealing

Source: Da Wei Energy
Other Form of Methanol Burners – Tobacco Drying

- Tobacco drying rooms can be retrofitted to burn methanol to produce exhaust gas for tobacco drying.

- Methanol burns clean with high concentration of CO2 which retains the quality of tobacco leaves.

- Coal and natural gas do not burn as cleanly, coal is also banned in some regions.

- Each room is equipped with sensors for CO, NOx, SOx, CO2, temperature etc.

- Each room consumes 2 tons of methanol per season; there are 1.2 million drying rooms in China.

Source: Da Wei Energy
METHANOL AS A COOK STOVE FUEL
Different Methanol Cook Stoves

• A methanol cook stove composed of a methanol fuel storage tank, supply pump, tank, and the stove itself.

• Different forms methanol Cook Stoves: Single stove, dual stoves for stir frying, steaming

• Fuel: 100% methanol to methanol blends (emulsified with water), stored in day tank/cylinder for small amount in the kitchen, and large amount stored outside the kitchen

• Widely used in restaurants, central kitchens: mainly cost driven, to replace LPG and NG (due to safety and cost concerns)
Usually called “Alcohol Based Fuel”, complying with two Standards: Alcohol Based Liquid Fuel and Stove for Alcohol based domestic fuel NY312-1997

Market for Cooking Application estimated over 5 MMTs in China in 2017.
### Economics and Status

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Methanol</th>
<th>Natural Gas</th>
<th>Liquefied Petroleum Gas</th>
<th>Diesel</th>
<th>Coal</th>
<th>Electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price per unit mass</td>
<td>¥3.4/kg</td>
<td>¥1.85/m³</td>
<td>¥9.2/kg</td>
<td>¥8.7/kg</td>
<td>¥0.4/kg</td>
<td>¥0.78/kWh</td>
</tr>
<tr>
<td>Price per kcal (¥0.0001/kcal)</td>
<td>6.4</td>
<td>2.2</td>
<td>8.1</td>
<td>8.6</td>
<td>0.8</td>
<td>9.1</td>
</tr>
<tr>
<td>Thermal Efficiency</td>
<td>56%</td>
<td>75%</td>
<td>50%</td>
<td>40%</td>
<td>30%</td>
<td>80%</td>
</tr>
<tr>
<td>Actual Economics (¥0.0001/kcal)</td>
<td>11.4</td>
<td>2.9</td>
<td>16.2</td>
<td>21.5</td>
<td>2.7</td>
<td>11.4</td>
</tr>
</tbody>
</table>

- The prices used are the consumer received prices in the field investigation.
- Methanol is cheaper than LPG.
- Chinese kitchens (large capacity for hundreds people) and restaurants have very limited connection to NG pipelines due to high infrastructure cost.
- Methanol as liquid fuel has superior Capex benefit to NG.
- Diesel and coal are banned to be used in China.
Different Attitude at Local Government Level

- Regions like Tianjin, Gansu, Shanxi, Shanxi, Guilin and Gansu supportive

- Regions like Xiamen, do not allow

- Difference dependent on how safely methanol fuel distributed, local cooking fuel supply conditions, company-government engagement, etc.
CONTACTS
Contacts

Zhao Kai
Chief China Representative
kzhao@methanol.org

Eelco Dekker
Chief EU Representative
edekker@methanol.org

Greg Dolan, CEO
gdolan@methanol.org

Larry Navin, Senior Manager,
External Affairs and Operations
lnavin@methanol.org

Nov Bajwa, Operations & Web/
Media Coordinator
nbajwa@methanol.org

Chris Chatterton, COO
ccchatterton@methanol.org

Timothy Chan, Manager
Government Relations and
Business Development
tchan@methanol.org

Belinda Pun, Executive Manager
bpun@methanol.org

www.methanol.org  www.methanolfuels.org