CHEMSYSTEMS
PERP PROGRAM

Dimethyl Ether (DME) Technology and Markets

New DME Applications (e.g., Fuel), Process Technology & Production Cost Comparisons - One Step (Haldor Topsoe, JFE, Kogas), Methanol Dehydration Two Step & Liquid Phase (Air Product's LPDME) Processes, and Global Supply/Demand Forecasts.

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Nexant

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INTRODUCTION

Dimethyl ether (DME), also known as methyl ether, methyl oxide, and wood ether is a colorless liquid or compressed gas.

DME has historically been used as a propellant in consumer products. DME can be used in a wide variety of consumer applications, namely personal care (e.g., hairspray, shaving creams, foams, and antiperspirants), household products, automotive, paints and finishes, food products, insect control, animal products, and other related applications.

DME is commonly used in organic synthesis as a reaction solvent for systems requiring volatile polar solvents.

A new and potentially large volume application of DME is as a fuel. Promising fuel applications include:

- LPG Blending and Substitute
- Diesel Blending and Substitute
- Power Generation
- Acetylene Substitute

Recently, China has been blending DME with LPG in significant volumes, and for reasons discussed later in this report, the Chinese government has been promoting DME blends. Egypt is also developing a DME project to reduce dependence on LPG imports.

The properties of DME suggest that it could be a substitute for diesel as a transportation fuel, with the attraction of enhanced environmental performance. Several bodies are actively researching the use of DME as a substitute for diesel vehicle fuel. The IEA (International Energy Agency) is co-coordinating research as part of the Implementing Agreement on Alternative Motor Fuels (IEA/AMF). Among the many organizations involved are automotive manufacturers such as Volvo, Renault and Peugeot. Volvo has developed a DME fuelled engine for buses. In Japan, a number of demonstration vehicles and small scale filling stations have already been built. Early tests by a number of companies have shown promising fuel efficiency results compared with traditional diesel vehicles. Programs on cars are also being promoted in North America and Western Europe.

Advantages and disadvantages of these new commercial applications, as well as DME chemistry, developing process technologies, and economic analysis are discussed in this ChemSystems PERP report. Brief highlights of some of the topics covered in the report are given below.

CHEMISTRY

Dimethyl ether is produced in a minimum of two steps. First, hydrocarbons (predominant feedstock for DME production is natural gas) are converted into synthesis gas, a combination of carbon monoxide and hydrogen. The synthesis gas is then converted into DME, either via methanol (conventional process) or directly in one step (Haldor Topsoe or JFE Holdings).

The predominant feedstock for DME production is natural gas. The different reactions occurring are:

Reaction	Chemistry			$\Delta H°_{298K}$ (kJ/mol)
Partial oxidation reforming	$CH_4 + ½ O_2$	$\longrightarrow$	$CO + 2 H_2$	-36.0
Steam reforming	$CH_4 + H_2O$	$\longrightarrow$	$CO + 3 H_2$	206.0
Gas/water shift reaction	$CO + H_2O$	$\rightleftharpoons$	$CO_2 + H_2$	-40.9
Methanol synthesis	$CO + 2 H_2$	$\longrightarrow$	CH_3OH	-50.1
	$CO_2 + 3H_2$	$\longrightarrow$	$CH_3OH + H_2O$	-50.1
Methanol dehydration	$2 CH_3OH$	$\longrightarrow$	$CH_3—O—CH_3 + H_2O$	-23.3
DME direct synthesis	$4 H_2 + 2 CO$	$\longrightarrow$	$CH_3—O—CH_3 + H_2O$	
Overall DME synthesis	$2 CH_4 + O_2$	$\longrightarrow$	$CH_3—O—CH_3 + H_2O$	

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Current commercial synthesis gas technologies include steam methane reforming, partial oxidation, autothermal reforming, and combined reforming. Technologies under development include compact reformers and ceramic membranes.

Catalysts

Two step process:

Methanol and shift catalysts are typically copper based. Increasing temperatures rapidly decrease catalyst activity so that isotherms need to be carefully controlled.

Different types of catalysts are employed for methanol dehydration. Of these, the catalytic activity of γ-alumina and silica-alumina catalysts has been investigated more thoroughly than most.

One step (direct) process:

The direct synthesis of DME (or single step) process requires a dual catalyst system that acts as a methanol synthesis catalyst and a methanol dehydration catalyst in a single unit.

In the 1990s, Air Products and Chemicals discussed the use of $Cu/ZnO/ \gamma\text{-}Al_2O_3$ shift catalysts as a single catalyst for single step processes.

Studies of catalysts for direct DME synthesis, in the 2000s, include a patent granted to JFE Holdings. Other single step catalysts are also under investigation.

TECHNOLOGY

Section 3 reviews the technical features of commercially available processes offered by the major licensors of dimethyl ether technology. Features and advantages will be specified for several Two Step technology process while detailed process descriptions will be given for One Step and Liquid-Phase dimethyl ether processes.

Two-Step Processes

The only current commercial two step technology process in use for the production of DME is via fixed bed catalytic dehydration of methanol. Because the process is relatively simple, this method is commonly used because of the low capital investment required and the availability of feedstock.

Currently, there are several licensors that offer technology for the production of dimethyl ether based on a two step process. These include Haldor Topsoe, Lurgi, Mitsubishi Gas Chemical, Toyo Engineering Corporation, and Uhde. Distinguishing features of the various two step processes for these licensors will be given in this report.

One-Step (Direct) Processes

Haldor Topsoe has developed a process technology for large scale production of DME via direct synthesis from natural gas, without having to first produce and purify methanol. A detailed description is given in section 3.3.1.

In 2002, DME Development Co. (a consortium of ten companies including JFE) started a five year development project which involves the operation of a demonstration plant. JFE claims that the results of the test operation proved the process technology and the catalyst performance of the slurry phase reactor and that the scale-up technology was established. Consequently, JFE is ready to license the process and supply the catalyst. This process description is given in section 3.3.2.

Since December 2004, Korea Gas Corporation (Kogas) has been involved in a project that includes the development of a new DME process as well as the research and development of a high performance catalyst for DME synthesis reaction. Section 3.3.3 describes the Kogas process technology.

Liquid-Phase Processes

Air Products and Chemicals, as part of its research program with the Department of Energy's Clean Coal Technology and Alternative Fuels programs, has developed a liquid phase methanol synthesis process, the LPMEOH™ process. The same basic technology has been used to develop a one step liquid phase DME from syngas synthesis process, the LPDME™ process.

ECONOMIC & COMMERCIAL ANALYSIS

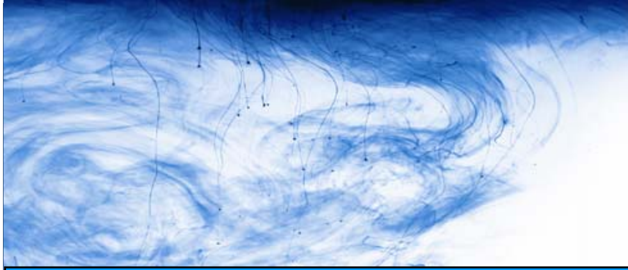
Several regions and processes have been considered for the production of dimethyl ether. Production cost estimates for dimethyl ether, based on natural gas and coal, have been included in section 5. Furthermore, production cost estimates have been generated for methanol (from natural gas and coal) since it is the raw material used in the production of dimethyl ether (DME). The full cost of methanol was used as the basis for the transfer price of methanol for the production of dimethyl ether. Capital cost for air separation units, gasification, etc., have been included into the cost estimate of methanol production.

The selected cases are:

- Dimethyl ether (Middle East, Methanol Dehydration Two Step Process, Natural Gas)
- Dimethyl ether (China, Methanol Dehydration Two Step Process, Coal)
- Dimethyl ether (Middle East, One Step Process, Natural Gas)
- Dimethyl ether (China, One Step Process, Coal)
- Dimethyl ether (USGC, LPDME Process, Natural Gas)

In developing a cost of production analysis, utility and labor pricing were taken from Nexant's fieldwork and are representative of facilities located in the United States Gulf Coast (USGC), Middle East, and China. Raw material prices are representative of quarter average prices paid by a large end user for bulk shipments under contract. Details of Nexant's *ChemSystems* investment estimates are provided in Appendix A.

Section 6 discusses commercial uses, global supply/demand (demand by Asia, and supply from China, Japan, and Iran).



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