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NATURAL GAS: ALTERNATIVE SOURCE OF LIQUID FUELS

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The primary use of natural gas in Canada is as a stationary fuel (domestic heating and large industries). It is also used for chemicals manufacture (hydrogen, methanol), and export to the U.S.A. It has been suggested that there will be increased opportunities for export, in a few years, when the current U.S. reserves of natural gas have diminished. On the other hand, one study (1) has indicated that additional large quantities of gas will be identified within the U.S. At the moment the future volume of the export market cannot be predicted with certainty.

An alternative use would be to convert natural gas to a transportation fuel. Canada's reserves of conventional petroleum are declining and oil sands plants to produce synthetic crude oil which would replace conventional crude oil, are extremely capital intensive. The production of synthetic crude oil from natural gas might be considered as an alternative or supplement to synthetic crude from oil sands.

Specifications for adding methanol (manufactured from natural gas) to gasoline are currently being developed (2) for Canada. Instead of methanol another option would be to convert natural gas to a high octane aromatic fuel component (benzene, toluene) which would command a premium price as a gasoline blending stock. Similarly a high cetane number paraffinic fuel component would command a premium price as a diesel fuel blending stock.

Some of the processing routes for converting natural gas to liquid fuels are indicated in Figure 1. The solid lines represent the more established routes. Research reports (3-17) which have derived at least partial funding from Energy, Mines and Resources are referenced in Table 1.

At least two of the routes in Figure 1 (steam reforming/Fischer Tropsch and steam reforming/methanol synthesis/methanol to gasoline (MTG) ) can be considered to have operated on a commercial scale. Steam reforming (18) is used extensively in Canada to convert natural gas into  $H_2 + CO$  and subsequently to  $H_2$ . Fischer Tropsch (19) has been used for many years in South Africa. Although the Fischer Tropsch process operates well, a wide spectrum of products are produced and much research (3-5, 20) directed at improvements is in progress. One project within our laboratory is directed at the selective production of diesel fuel.

A commercial plant combining steam reforming, methanol synthesis (21) and a fixed bed version of the methanol to gasoline (MTG) process (22, 23) has been constructed in New Zealand. A demonstration plant having a fluidized bed version of the MTG process has operated in West Germany (23). A vital part of the MTG process is the ZSM-5 catalyst, which has stimulated considerable interest (10).

A great deal of research effort has been focussed on improving the steam reforming/methanol synthesis/MTG process sequence. Haldor-Topsoe has developed the TIGAS process (27) which retains all three processes but operates them all at the same pressure. Another approach has been to eliminate methanol as an intermediate, by converting synthesis gas ( $\text{CO} + \text{H}_2$ ) directly to gasoline (8, 9, 24, 25). Still another is to eliminate the formation of synthesis gas by forming methanol from the partial oxidation of methane (11-13,26).

There are alternative processing routes which also require three processing steps. Figure 1 shows steam reforming, followed by olefin synthesis (28), followed by alkylation/oligomerization. Interestingly enough some research has resulted in a processing route which actually increases the number of processing steps. This route is shown in Figure 1 as steam reforming, followed by the methanol synthesis process, followed the methanol to olefins (MTO) process, followed by alkylation/oligomerization (23) or methanol olefins to gasoline diesel (MOGD).

In an attempt to decrease the number of processing steps, work within our laboratory was directed at a processing route in which acetylene is an intermediate(29). This route is shown on the right hand side of Figure 1. Both electric arc (30) and plasma (31) processes have been used on a large scale to convert natural gas to acetylene. The second step involves the polymerization of acetylene to aromatics and related products. This route virtually becomes a single process step because the acetylene is formed at high temperature and therefore can be polymerized directly in a second reactor as its temperature decreases.

There is another two step route shown in Figure 1. In oxidative coupling, methane reacts with some species such as oxygen or chlorine to form ethane and/or ethylene and by-products such as  $\text{H}_2\text{O}$ ,  $\text{HCl}$  or chlorinated hydrocarbons. In the second step the  $\text{C}_2$  molecules are then reacted to form a liquid of greater molecular weight(32).

The ideal processing route is the one shown on the extreme right of Figure 1. In this route methane is converted directly to a liquid fuel. Unfortunately this ideal has not yet been achieved. However it is clear that any processing route which approaches this ideal will be highly desirable.

#### Summary

Many routes for converting natural gas to liquid fuels are being investigated. In Canada the conversion of natural gas could be used in three ways: the production of a synthetic crude oil to replace the declining reserves of conventional crude oil; the

production of a high octane gasoline component to replace the tetraethyl lead currently being phased out of gasoline; the production of a high cetane number diesel fuel component to supplement the low cetane diesel fuel derived from Canadian oil sands. Of the various possibilities discussed in Figure 1, no one best route is currently obvious. Researchers in our laboratory, as well as in other laboratories are continuing to search for the optimum route to fuel products.

TABLE 1  
 REPORTS FROM CONTRACT FUNDS  
 PROVIDED BY ENERGY, MINES AND RESOURCES CANADA

REACTION	REFERENCES
Steam Reforming/Fischer Tropsch	3-5
CO + H <sub>2</sub> ---> Gasoline	6-9
Methanol Conversion	10
Methanol Synthesis	11-13
Acetylene Synthesis	14-16
Oxidative Coupling	17

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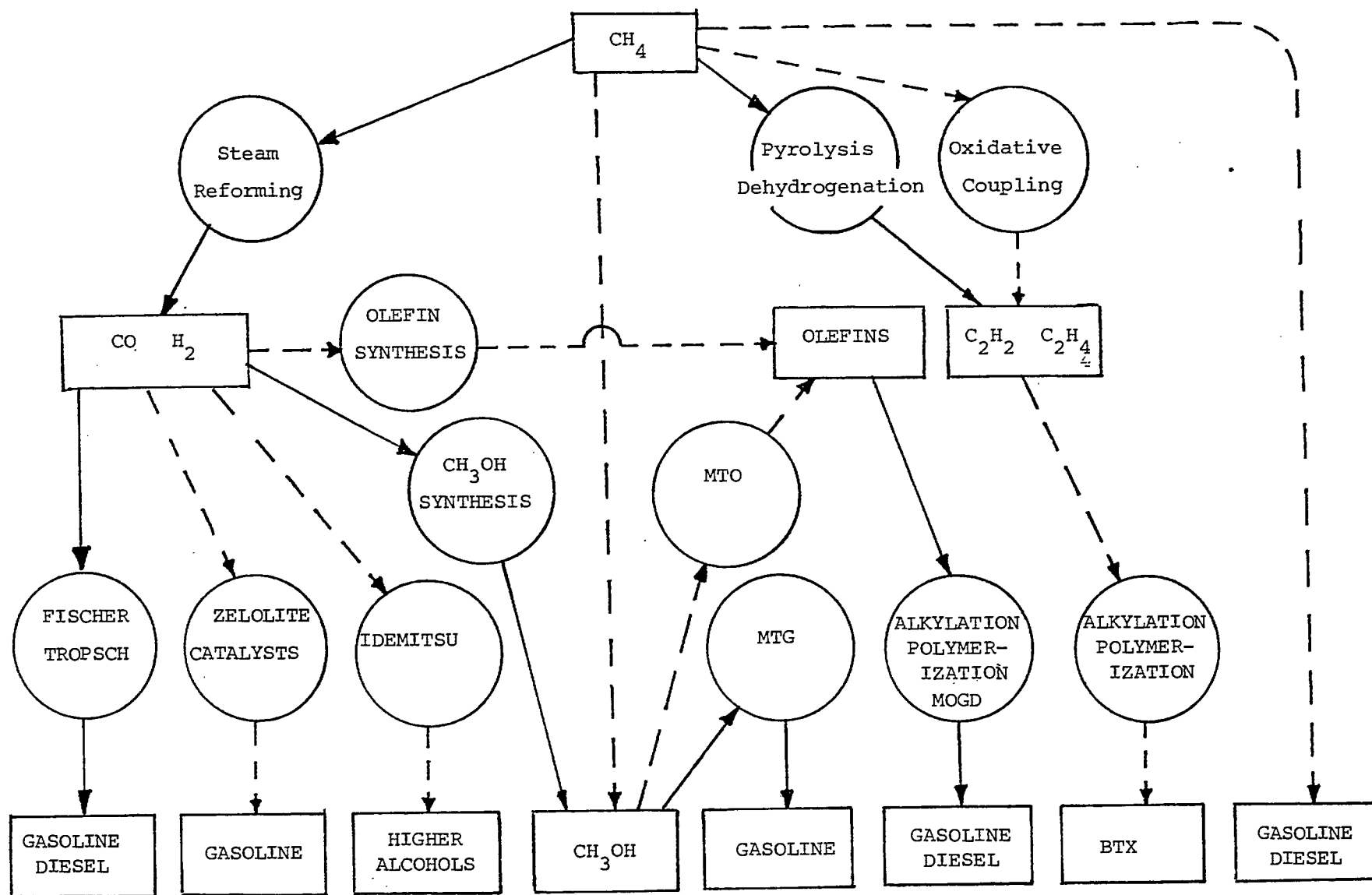


FIGURE 1 SOME ROUTES FOR THE CONVERSION OF NATURAL GAS TO LIQUID FUELS