CHAPTER 1

INTRODUCTION

Gas-to-liquids (GTL) conversion technology, where natural gas is chemically converted to transportable hydrocarbon liquid products, is an emerging technology that is expected to reach commercialization within the next decade. One of the first areas in the United States to exploit this technology will be the Alaskan North Slope (ANS). The proven and recoverable reserves of conventional natural gas in the developed and undeveloped fields in the Alaskan North Slope (ANS) are estimated to be 38 trillion standard cubic feet (TCF). In addition to the known reserves, estimates of undiscovered gas reserves in the Arctic fields range from 64 TCF upwards to 142 TCF. Currently, only a small portion of the produced natural gas on the North Slope of Alaska is used in the oil-field operation, such as gas lift and power generation, and in local sales. The unused portion is injected back into the reservoir for pressure maintenance and oil production. It is expected that as crude oil production on the North Slope continues to decline, approximately 26 TCF of ANS natural gas will become available for gas sales, transportation and/or conversion to GTL products.

Several options exist for ANS gas utilization/transportation. The two most promising options are: (i) transportation of the gas via a new gas pipeline, called as the Trans-Alaska-Gas-System (TAGS) followed by Liquefaction to LNG and then to Pacific-Rim markets via LNG tankers, and (ii)conversion of the gas to GTL products followed by transportation via the existing Trans-Alaska-Pipeline-System (TAPS). In a recent study by Robertson et al. (1996), it was concluded that the TAGS/LNG and the GTL options appear economically promising and warrant consideration in the decision-making process. Moreover, the future market for ANS-LNG is less certain than a potential market for GTL products. The throughput of oil through the TAPS has been on decline and is expected to continue to decline in the future. Currently, 4 of the 12 pump stations have been shut down due to decline in TAPS throughput. It is projected that by the year 2015, ANS crude oil production will decline to such a level (200,000 to 400,000 bbl/day) that there will be critical need for pumping additional liquid from GTL process to provide an adequate volume for economic operation of the TAPS. The pumping of GTL products through TAPS will significantly increase the economic life of TAPS. Some of the reasons for considering transporting GTL products through TAPS are: 1) monetize ANS gas resources; 2) use existing oil pipeline and other transportation infrastructure for GTL transport; 3) declining ANS oil production; 4) declining ANS oil production increases the cost of oil transportation through TAPS; 5) GTL products are refined products and will receive premium compared to crude oil; 6) GTL transport will increase pipeline throughput.

This project addresses the study of GTL product transportation through the existing Trans Alaska Pipeline System (TAPS). Alyeska Pipeline Service Company (APSC), the TAPS operator, will work closely with UAF in all aspects of this project. Such a study is necessary for successful future commercialization of GTL technology in Alaska. The technical and economic factors, and transportation issues that affect the feasibility of moving GTL products through the TAPS are identified. Various commercial and pilot GTL conversion technology are reviewed and compared. A program for testing GTL materials and GTL/crude oil blends is designed and implemented. Hydraulic models, including thermodynamic considerations, are

developed to study flow behavior of GTL products through TAPS. Finally, a preliminary economic analysis of GTL transportation through TAPS is performed.

1.1 PROJECT OBJECTIVES

The objective of this project is to evaluate the transportation of Alaskan North Slope (ANS) Gas-To-Liquids (GTL) products through the existing Trans Alaska Pipeline System (TAPS). The main purpose of this proposed project is to evaluate technical and economic feasibility of TAPS as the transportation method for the movement of GTL products. This will require an in-depth understanding of the GTL product characteristics and the relative behavior (i.e. fluid properties, mixing phenomena, and downstream separation characteristics) of mixtures or blends of the GTL products with the North Slope crude oil.

The main objectives of this project are as follows:

- To identify various transportation issues related to GTL products transport through TAPS and gather relevant information and data.
- To identify types of GTL material that could be moved through TAPS either as individual batches (slugs) or commingled with crude oil and to design a program for testing properties of these materials.
- To implement the material testing program for various GTL and GTL/crude oil blends.
- To determine the flow behavior of GTL and GTL/crude oil blends through TAPS for various GTL transportation modes.
- To provide an overall technical and economic assessment of various options of GTL transportation through TAPS.

1.2 PROJECT TASKS

The tasks envisioned in the original proposal are described below.

Task 1 – Information Required for the National Environmental Policy Act (NEPA)
The Department of Energy (DOE) shall prepare the appropriate level of NEPA documentation for the project. The University of Alaska Fairbanks (UAF) shall provide all the necessary information for the completion of this documentation.

Task 2 – Determination of TAPS Transportation Issues
The objective of this task is to identify various transportation issues related to transport of GTL products through TAPS and to gather relevant information and data. To accomplish this goal, meetings will be arranged at the beginning of this project with Alyeska Pipeline Service Company (APSC), which operates TAPS, in order to explore the issues of possible movement of GTL material through TAPS. The issues to be discussed with the TAPS operator will include (but not limited to) the following:

1. What would be the volume availability in future years for the possible movement of GTL materials through TAPS?

2. What are the potential ways of moving GTL product through TAPS? Would GTL product have to be commingled with crude oil or would it be possible to batch GTL product through the line?
3. Determine the temperature and flow conditions in TAPS and any physical property requirements for liquids moved through the system. Gather information on the range of crude oils that have been moved through TAPS and if any problems have been encountered in the past.
4. If GTL batch movement appears to be a practical possibility, gather preliminary information on issues for movements: length of time of batch cycles, degree of mixing at interfaces, other operational issues.
5. Discuss any other flow issues with the TAPS operator such as line heating capabilities, corrosion issues, pumping, cost, etc.

Task 3 – GTL TAPS Movement Options and GTL Material Testing Program Design

The objective of this task is to identify types of GTL material that could be moved through TAPS either as individual batches or commingled with crude oil and to design a program for testing properties of these materials. The primary focus will be on a range of products from Fischer-Tropsch (FT) type processes. The range will include lighter (higher gasoline yield) to heavier GTL products, with and without upgrading (such as hydrocracking to deal with conversion of heavier wax components), oxygenated liquids such as alcohols or ether mixtures produced by catalytic reforming processes. A program for testing of the properties of materials before pipeline movement and after movement will be designed. In case of commingled material, the test program will analyze what the quality attributes of the individual boiling range fractions would be when the material is distilled at a refinery after it has been moved through the pipeline and delivered to a refinery at a distant market location. Designing a GTL material testing plan will entail the following.

- Gather product quality data for GTL products for various types of FT process schemes. These will include raw products with different possible carbon number ranges and upgraded products assuming possible levels of upgrading. Also gather assay data for North Slope crude oils and crude blends with which GTL product could be blended for transport through TAPS.
- Develop an outline of the physical and chemical property tests that are needed to assess how GTL and GTL/crude blends will behave in the TAPS environment. If questions concerning stability of products during storage exist, these will also be addressed.
- Design tests to provide information on schemes involving commingling GTL product and crude oil on the transportability, costs, and value of GTL/crude blends in refinery market locations. This will include some level of assay for delivered commingled blends with detailed quality data testing for gasoline and distillate boiling range fractions. The commingled blends will span a reasonable range of percents of GTL in the blends.
- Arrange for acquisition of samples of GTL and North Slope crude oils to carry out test program

Task 4 – Test Program for GTL and GTL/Crude Blends
This task will consist of carrying out the test program developed in Task 3, analyzing the results and studying their impact on GTL transportation issues.

Task 5 – Study of TAPS Flow Behavior
Two modes of transportation of GTL products through TAPS oil pipeline to Valdez Terminal will be considered. These are: 1) sending a certain size of slug of GTL products intermittently between the crude oil transport (batch movement or slugging); and 2) blending the GTL products with crude oil prior to transportation via TAPS (commingling). The objective of this task is to develop information needed to comparatively analyze batch movement of GTL product through TAPS with movement of a commingled blend of crude and GTL product.

For batch movement options, estimate the impact on overall throughput and costs of batch operation. Will there be an increased likelihood of operational problems with downtime and cost implications? Estimates on factors determining and limiting batch cycle lengths will be determined. Pipeline fluid flow simulation study will be conducted to determine the degree of intermixing at the interfaces during GTL batch transport and the volume fraction of GTL material downgraded will be estimated. A minimum slug size of GTL product needed to be transported via 800-mile long, 48-inch diameter TAPS without full disintegration of the slug due to mixing will be determined. The impact of batch cycle lengths (or slug size) on the costs of batch operation will be estimated. Other operational problems that may result from batch flow operations will be described.

The costs and operational problems for shipping commingled GTL/crude blended will be analyzed for comparing with GTL batch shipment options. The fluid flow simulations will also be done for blending cases. The compositions of the GTL-crude oil mixtures at the end of TAPS will be determined and compared for the two modes of transportation.

Task 6 – Overall Evaluation of GTL Transport Modes
In this task, the results of the previous tasks will be integrated to provide an overall assessment of the options for transporting GTL on Alaska's North Slope. For the slugging mode, storage requirements for GTL and crude oil at both ends and additional capital investments, pump-station load factors, blending and separation costs for different GTL slug sizes will be determined. Optimal size of GTL liquid slug will be determined from the economic analysis. For the blending mode, storage requirements for GTL and crude oil at both ends and additional capital investments, pump-station load factors, blending and separation costs for different crude oil – GTL blends will be determined. Optimal blend ratio will be determined from the economic analysis. The two modes of GTL transportation will be evaluated on the basis of cost to benefit ratio. While economic evaluation of GTL process options will have been developed by DOE contractors and process development firms, it would be useful in the course of this project to provide information on cost impacts of building and operating process facilities on the North Slope. The contacts with North Slope operators could be helpful in achieving this objective.

Task 7 – GTL/TAPS Transport Assessment and Final Report
A comprehensive evaluation of all data collected in Tasks 2-6 will be conducted and a final report assessing the feasibility of utilizing TAPS as a transportation vehicle for GTL produced on the Alaskan North Slope will be submitted to the Department of Energy for review and approval.

1.3 GTL TRANSPORTATION ISSUES

Since the Trans Alaska Pipeline System (TAPS) was designed to carry a specific type of crude oil with no provision for batching, the possibility of flowing GTL products through TAPS gives rise to numerous questions. These questions or the transportation issues are dynamic and continue to evolve. Addressing all of these issues is not feasible within the scope of the present study. The following is a summary of the transportation issues that were identified in collaboration with Alyeska Pipeline Service Company (APSC).

- Effect of solids (wax and/or asphaltene) precipitation within the pipeline. Metering of a fluid stream containing solids may pose problems.
- Effect of cold temperature on the GTL material.
- Impact of GTL transport on internal monitoring of corrosion and pigging. Ultrasonic/magnetic properties of the transported fluids will affect monitoring programs. Additionally, GTL may interact with corrosion inhibitors.
- Impact of GTL batching on local refinery (Petrostar, MAPCO) operations. Vapor recovery and volatility of the downstream end product will have to be estimated. The need for adding another berth for vapor recovery will have to be considered.
- Impact on existing metering systems. The TAPS was originally designed for a single grade crude oil system with no provision for batching different fluids.
- Interaction of Drag Reducing Agents (DRA) with GTL.
- Fluid deliverance i.e. ability to transport crude oil and GTL batches or blends. The TAPS was specifically designed for Prudhoe Bay crude, which has a gravity of 24°API to 32°API. On the other hand, GTL has much higher API gravity than Prudhoe Bay crude. In future, as crude oil volume decreases, GTL to crude oil ratio will increase. This is to be considered in the analysis.
- Gelling and cold restart issues. Temperatures at which GTL gelling occur, and gel strengths will need to be determined to address cold restart problems.
- Contamination of GTL product by wax. Wax buildup on the pipeline interior may redissolve in GTL causing contamination and change in GTL properties.
- Mixing at the oil-GTL interface in case of batch mode of transportation.
- To take elevation into account in all Batching/Blending calculations. Here, Austin and Palfrey correlation or derivations by Levenspiel may be used.
- Comparison of simulated mixing behavior with the real mixing behavior by actually testing the samples in slackline. Red Dye Test is used by Alyeska for this purpose.
- GTL compatibility issues which include stripping of asphaltenes, resins, and compatibility for valves, seats.

- Gel strength and vapor pressure are the critical parameters, which will govern the limits on crude oil and GTL blending ratios. Therefore, gel strength and vapor pressure measurements are of utmost importance.
- Effect of solids buildup (wax and asphaltenes) continues to be of great concern. There is need to study the composition and source of wax, and the effect of asphaltene on wax.

It is obvious from these transportation issues that using the TAPS to move GTL products is far from being a simple matter of switching fluids in the pipeline. Fluid properties and the hydraulics of flowing GTL products and GTL-crude oil blends through TAPS will have to be thoroughly studied before making any decision regarding feasibility of such processes. This project will, therefore, focus primarily on fluid property measurement and development of hydraulic models for studying GTL flow through the TAPS. Finally, an economic analysis will be incorporated to examine the economic feasibility of GTL transportation.

BIBLIOGRAPHY

Robertson, E.P., Thomas, C.P. and Avellanet, R.A.: "Economics of Alaska North Slope Gas Utilization Options," paper presented at the SPE Western Regional Meeting, Anchorage, Alaska, May 1996.

"1995 Assessment of United States Oil and Gas Resources," US Geological Survey, Circular No. 1118, 1995.

"Natural Gas 1994, Issues and Trends," DOE/EIA Report No. 8520, July 1994.

Malone, R.D. and Komar, C.A. (Eds.): "Natural Gas to Liquids" Technology Status Report, Morgantown Energy Technology Center, US DOE, DOE/METC-89/0265, Jan. 1989.

Sharma, G.D., Kamath, V.A., Patil, S.L. and Godbole, S.P.: "The Potential of Natural Gas in the Alaskan Arctic," paper SPE 17456, Proceedings of the SPE California Regional Meeting, Long Beach, CA, March 1988, pp. 515-523.