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QUARTERLY PROGRESS REPORT

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PROJECT: Research Guidance Studies (DE-AC22-95PC95054)

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Section 1 Introduction

The Pittsburgh Energy Technology Center (PETC) of the United States Department of Energy contracted with the MITRE Corporation to perform Research Guidance Studies that will assist the Center in evaluating and prioritizing research in the areas of coal and natural gas conversion. MITRE was reorganized in December 1995, which resulted in the formation of Mitretek Systems Inc. Mitretek is performing this work on MITRE's behalf until completion of contract novation to Mitretek.

The overall objective of this project is to provide research guidance and quantification of research progress in the areas of direct and indirect coal liquefaction, coal/waste coprocessing, refining of coal-derived liquid fuels, and natural gas conversion. Specifically, the work is divided into two subtasks that relate to whether the technology application is direct or indirect. In subtask (a), *Direct Coal Liquefaction* technology is the subject of the analyses, and in subtask (b), *Indirect Liquefaction*, technologies will be evaluated in accordance with the priorities of the COR.

Mitretek Systems has been developing detailed computer simulation models of direct and indirect coal and natural gas conversion systems for several years. These models are constantly being updated and improved as more data and better cost information becomes available. These models also include detailed refinery models based on bench-scale upgrading data of coal derived liquid fuels to specification transportation fuels. In addition to the simulation models of actual conversion system configurations, Mitretek is able to simulate innovative process configurations for coal and gas conversion to fuels, power, and chemicals. To supplement these system models and to provide a context to investigate expected energy use scenarios when alternate coal and natural gas based fuels will be needed, Mitretek's staff has also developed world and country by country energy supply and demand models. This work will be accomplished by using the existing models where appropriate and by extending and modifying the system models where necessary.

Section 2 Project Activity Summary

General Overview of Technical Activities:

During this second quarter of the contract, the main emphasis was on the rationale and strategy project for the deployment of coal-derived liquid transportation fuels and on the concept of integrating both direct and indirect liquefaction technologies with existing refineries.

For the rationale section of the project, a detailed analysis of the world oil situation was performed including historical data to the present and projections based on the Energy Information Administration (EIA) data until the year 2015. Beyond that date, Mitretek used its own analysis of future trends based on the availability of ultimate world oil resources. Next, an analysis of the United States oil situation was performed. Again, historical data was used, followed by EIA data from their current Annual Energy Outlook report of 1996 until the year 2015. Beyond that, Mitretek used an extrapolation of likely trends in transportation use until the year 2040. The analysis of transportation trends includes the impact of oil use for transportation, the impact of improved fuel efficiency in the transport sector, and the impact of the penetration of alternatively fueled vehicles.

The current status of this project is that the world oil situation is complete and the U.S. oil situation analysis is almost completed. The target date for completion will be May so that a draft report incorporating all these analyses will be ready for review by DOE.

For the strategy section of the project, the concept of pioneer plants has been introduced as small-scale commercial facilities that would demonstrate the technologies. The pioneer plant for direct liquefaction has been configured and analyzed during this quarter. This plant is a waste plastics/coal coprocessing facility adjacent to an existing refinery. The plant produces hydrogen from petroleum coke that is used for the liquefaction plant and excess hydrogen is sold to the refinery. The direct plant configuration uses the Hydrocarbon Technologies Inc. (HTI) process to produce liquid fuels that are sent to the refinery for upgrading.

For indirect liquefaction, two pioneer plant configurations are being investigated and analyzed. One of these is located adjacent to an existing refinery and uses petroleum coke as feed to gasification. The synthesis gas is then used in Fischer-Tropsch reactors to produce high quality liquid fuels that are blended in the refinery to make gasoline and diesel fuel. The unconverted synthesis gas is sent to a combined cycle power plant to produce electric power for the adjacent refinery. The second pioneer plant is located at an existing Coal Gasification Integrated Combined Cycle (IGCC) facility. In this configuration, the synthesis gas from the coal gasifiers is processed in Fischer-Tropsch reactors to produce liquid fuels. Natural gas is used in the gas turbines to keep the plant running at the designed power output. This project is on schedule and it is expected that a

draft report incorporating the rationale and strategy sections of the project will be ready for review by DOE by the beginning of June.

TASK 1: (subtask (a)): Direct Coal Liquefaction:

During this quarter, analysis of the concept of integrating coal liquefaction facilities into existing oil refineries and Integrated Coal Gasification Combined Cycle (IGCC) plants was continued. Since the concept to be analyzed involves integration into an existing refinery, the first step in the analysis was to develop the baseline refinery. The baseline refinery model was developed assuming a size of 230,000 barrels per day (BPD)capacity to the stills. The refinery is assumed to process vacuum residual by means of delayed coking. The coker capacity is set at 28,000 BPD to produce approximately 1500 tons per day of low quality coke. The next step was to develop the future refinery upgrade that consists of increased coker capacity. It is assumed that future crude will be of lower quality with higher content of resid and higher sulfur. A refinery has several options that can be exercised to process this lower quality crude oil. The least cost option is to increase coker capacity. In the case analyzed, coker capacity is increased to process an inferior crude containing 20 weight percent resid compared to 14 percent in the baseline refinery. In the increased coker case, the coker capacity is increased to process 42,000 BPD of resid to produce approximately 2500 tons per day of coke. Capital costs of the baseline refinery and the increased coker refinery were estimated based on the cost simulation models developed. Daily operating costs for the two refinery options were also calculated and the resulting cost of products were estimated.

The next option analyzed was hydrocracking of the additional resid instead of coking. A resid hydrocracker was incorporated into the base case refinery that could process the additional resid from the stills. This unit was based on an H-OIL type process that used ebullated bed reactors to upgrade the resid into distillate. The resid not converted in the hydrocrackers was sent to the base case cokers to produce coker distillate and petroleum coke. Hydrogen for the hydrocrackers was provided by steam reforming of natural gas. The simulated configuration was then analyzed with respect to estimation of capital and operating costs, and production yields.

For the Rationale and Strategy project, the Mitretek World Oil Supply and demand model was updated by using the most recent ultimate resource estimates from the United States Geological Survey (USGS) and by using the most recent estimates of available extra heavy oils and bitumens. This data, in conjunction with demand estimates from the International Energy Agency (IEA), was used to construct world demand and depletion curves from the present to the year 2100. Similar oil depletion curves for the United States were constructed using the model using recent data from the Oil Resources Panel report. A strategy for deployment of coal-derived fuels was developed that uses the concept of pioneer and entrance plants to reduce technical risk and to allow the technology for stand-alone plants to be eventually deployed. The pioneer plants to be analyzed include a coal/waste pioneer plant sited adjacent to an existing oil refinery, an indirect Fischer-Tropsch plant integrated into an existing IGCC plant, and an indirect

plant that uses petroleum coke feed to gasification. These pioneer plants are currently being simulated and the capital and operating costs estimated. Financial analyses are being performed so that estimates of type and quantities of financial incentives can be determined.

The direct liquefaction pioneer plant was analyzed in detail. This plant was sited adjacent to an existing refinery and was configured so that it could process a variety of feedstocks including coal, coal and heavy oil, and coal and waste plastics, or combinations of these. The capital and operating costs were estimated based on actual run data from HTI run CMSL-09. Discounted Cash Flow (DCF) analyses were then performed on this plant for various assumptions of debt to equity financing, and investment tax write-off. The incentive of waiving State and Federal fuel taxes was investigated for this plant and the resulting return on investment (ROI) was calculated for various assumptions of fuel tax exemption. The overall conclusion from this analysis was that expected ROIs of 25 percent could be achieved if the fuel could command a premium of 10 cents per gallon over conventional petroleum and a state tax exemption equivalent to about 17 cents per gallon was applied.

The rationale section of the study was extended to investigate the transportation sector of the United States in more detail. Since the overall objective of the coal-derived fuels program is to provide high quality transportation fuels, it is the transport sector that is most impacted by this program. The impact of market penetration of alternative fuel vehicles like electric cars was also analyzed for assumptions of different rates of penetration of non-hydrocarbon liquid fueled vehicles.

Subtask (b): Indirect Liquefaction:

Two pioneer plant configurations were investigated for indirect liquefaction. In the first of these, the pioneer plant was assumed to be located adjacent to an existing refinery and that the petroleum coke from the refinery was used as feedstock to the gasification section. the synthesis gas was then sent to a slurry Fischer-Tropsch reactor system where approximately 3,500 BPD of liquid products and wax were produced. In addition, the unconverted F-T tail gas was used to produce about 35 MW of electric power for refinery use. Other integrations between the indirect plant and the refinery included recovery of sulfur from the acid gas and treatment of plant waste water by the refinery. The liquid and wax products were sent over the fence to the refinery for upgrading to transportation fuels. In the second configuration, the indirect plant was assumed to be sited at an existing IGCC facility. Since the site is an existing IGCC facility, the coal gasification and gas cleaning facilities and the combined cycle plant are already in place. To convert this facility into an indirect coproduction pioneer plant, only the gas polisher, the F-T unit, hydrocarbon recovery, and wax cracker need to be added. Because the coal-derived synthesis gas originally used in the combined cycle plant is now diverted to the F-T plant, natural gas is used to make up the synthesis gas so that the IGCC plant can produce the rated electric power. In the configuration analyzed, about 4,200 BPD of liquid fuels are produced together with 250 MW of net power. Currently capital and operating costs for

these facilities are being prepared so that a DCF analysis similar to that performed for the direct pioneer plant can be completed. This will determine the extent of the incentive required for an acceptable rate of return for both of these indirect pioneer plant configurations.