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Quarterly Progress Report

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By:
David Gray
Glen Tomlinson

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By
MITRETEK Systems
McLean, Virginia

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Section 1 Introduction

The Federal Energy Technology Center (FETC) at Pittsburgh 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 objectives of this support contract are to: (1.) evaluate the technical and economic merits of current direct and indirect coal liquefaction technologies and other similar emerging technologies such as coal-waste coprocessing, natural gas conversion, and biomass conversion technologies, (2.) monitor progress in these technologies, (3.) conduct specific and generic project economic and technical feasibility studies based on these technologies, (4) identify long-range R&D areas that have the greatest potential for process improvements, and (5.) preliminarily investigate best configurations and associated costs for refining coal-derived and other non-conventional liquids in existing petroleum refineries.

Mitretek has been performing work to achieve several of these above objectives for DOE since 1980. As a result Mitretek has developed specialized and unique databases and spreadsheet simulation models that are quickly and reliably used to evaluate new and emerging fossil energy technologies. More recently, Mitretek has worked closely with other DOE contractors to screen process alternatives and provide preliminary data and information required to set the basis for doing more detailed process studies using commercial process development techniques and software such as Linear Programming (LP) and Aspen Plus. Such preliminary screening saves significant time and money in accomplishing the subsequent, more expensive, detailed process studies. The Mitretek databases and spreadsheet models are continuously checked and updated, as required, with results obtained from the detailed process studies to maintain the validity of the spreadsheet models. In addition to simulating direct and indirect liquefaction systems, 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. The work to be performed in the current contract 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

2.1) General Overview of Technical Activities:

During this quarter, work was continued in the area of coal/oil coprocessing with existing petroleum refineries.

2.2) Continuation of Direct coal/resid coprocessing study:

To summarize the status of the study so far, Hydrocarbon Technologies Inc. (HTI) provided Mitretek with data from their bench unit run PB-01. For the purpose of this coal/resid coprocessing analysis, we have selected to use data from material balance period 25, a period where coal and resid were coprocessed together in a 50:50 weight mixture. In addition to yield and performance data, HTI provided details of recycle flows and composition, space velocity, and product and feed characteristics. This detailed data has been used to update the Mitretek direct liquefaction simulation model so that the model is representative of the performance of the advanced HTI COPRO process.

However, in recent communications with HTI, it was revealed that our interpretation of the space velocity data from run PB-01 for conceptual commercial facilities differed from the actual bench scale data. This could result in the simulation model predicting reactor volumes larger than necessary, and hence capital and resulting product costs could be too high. In order to resolve this discrepancy, we held meetings with HTI and DOE in Lawrenceville. As a result of these meetings it was decided that Mitretek reanalyze the space velocity data based on HTI feed rates to the bench-scale unit but with assumptions concerning potential commercial-scale gas hold-ups to estimate actual available reactor volumes. We have reanalyzed the HTI data with these new assumptions and have developed conceptual commercial designs based on this data for coal/oil coprocessing facilities integrated with both the generic and with the Valero petroleum refineries.

The promising technical performance of **coal/resid coprocessing** as demonstrated in the highly successful runs at HTI represents an opportunity for the introduction of coal into existing refineries and, therefore, for an early application of direct coal liquefaction technology. However, introduction of coal into a refinery would only occur if the resulting economics were feasible. Thus, the overall objective of the current task in direct coal liquefaction coprocessing is to investigate configurations and conditions where coal/heavy oil/resid coprocessing can be justified economically. In this current study, we investigated the integration of coal/resid coprocessing with a generic petroleum refinery that uses delayed coking for bottoms processing and with a specific refinery in Texas (the Valero refinery).

Considering first the integration into a generic refinery that uses coking to process the bottom products from the vacuum still. Coprocessing can be integrated into an existing petroleum refinery to provide distillate products that are compatible with the downstream refinery operations. A simplified schematic of this generic refinery/coprocessing integration is shown in Figure 1. The feedstock consists of 65,000 BPD of an average crude containing 20 volume percent 950°F+. In the generic refinery, the crude is sent to an atmospheric still where it is topped and the atmospheric bottoms are sent to a vacuum still. Vacuum gas oil (VGO) is recovered and the vacuum bottoms are sent to a delayed coker for processing. Coker distillate is recovered and the resulting coke is the final solid product. This coke is of low quality, containing heavy metals and high sulfur. It has a low value, probably about $3-5 per ton. This baseline generic refinery produces 59,684 BPD of C5-950°F distillate material consisting of atmospheric overhead, vacuum overhead, and coker distillate. LPG is also produced. This distillate material is then processed in the refinery downstream units to produce gasoline and diesel fuels including 760 tons per day of low value petroleum coke.

The conceptual coprocessing unit consists of two full-scale commercial trains of HTICOPRO and coal gasification for hydrogen production. The coprocessing unit processes 38,670 BPD of low value Hondo resid and 6,500 tons per day of coal. An additional 3,850 TPD of coal is sent to gasification for hydrogen production. Overall this coprocessing unit produces 45,858 BPD of C5- 850°F distillate, 13,535 BPD of resid, and 6,200 BPD of LPG. All of this material is sent to the refinery and integrated into the refinery's downstream units in the same way that the distilled crude was processed in the baseline case. In this coprocessing case, the refinery uses the coprocessing distillate in place of the 65,000 BPD of purchased crude. The additional 13,535 BPD of 950°F+ material is sent to the refinery from the coprocessing unit. This is sent to the delayed coker where 8,120 BPD of coker distillate is recovered and 773 tons per day of high quality coke is produced.

The quality of the distillate produced in the coprocessing unit is assumed to be compatible with the existing generic refinery's downstream processing capabilities. This is a reasonable assumption considering the reported high quality of products from the HTICOPRO process. The resulting quality of the coke product from the coprocessing case is assumed to be superior to the baseline coke. Since this material has undergone extensive hydrotreating prior to coking, it is assumed that the coke will be anode quality and thus worth $200 per ton. Because of this potential high value, the coke was not gasified to produce hydrogen for the coprocessing unit. Additional low value coal was used for hydrogen production.

The capital cost for the two-train coprocessing facility including hydrogen production is estimated to be $813 million. Feedstock costs for coal are $82 million, $48 million for catalyst and chemicals, $53 million for power (at $.04 per kWh) and total operating cost is $210 million. Net operating cost is $207 million after adjustment for refinery services and sulfur sales. In the baseline generic refinery, feedstock cost for crude oil at $20 per barrel is $429 million per year. Annual feedstock costs in the coprocessing refinery are only $128 million for the Hondo resid if it is assumed that the Hondo value is half of crude. If the coprocessing petroleum coke is worth $200 per ton, an additional $51 million per year in revenue can be realized through sales of anode quality coke, giving an overall annual feedstock cost savings of $352 million.

Figure 2 shows the return on equity (ROE) for this two-train coprocessing unit as a function of the world oil price, and for two prices for Hondo resid. Financial parameters used are detailed in Table 1. For the 33 percent equity financial assumption case, a 15 percent ROE can be obtained for this facility at an oil price of slightly less than $19 per barrel. This assumes that Hondo resid is half the cost of crude and that coal is $24 per ton. Thus in the current oil price range, a commercial size coprocessing facility integrated with the appropriate existing refinery could realize acceptable rates of return for investors. This observation is based on the assumed capital cost of the coprocessing facility, the level of technical performance shown, the relative feedstock costs, and the premium value obtained for the coprocessing coke. If Hondo resid could be obtained at a cost of $8 per barrel, a 15 percent ROE could be realized at a crude cost of $18 per barrel. Higher returns of 25 percent could be realized at a crude oil cost of about $20 per barrel.

Table 1. Economic Assumptions

- 33% Equity
- 8% Interest on Debt (16 Year Term)
- 3% General Inflation
- 34% Federal Income Tax Rate
- 8.75% State Income Tax Rate
- 1% State/Local Property Tax
- 1 Year Planning and Design
- 2 Year Construction
- 50% Available in Start Up Year
- Depreciable Capital (16 Year DDB)
  —Total installed cost TIC
  —Home office costs = 8.4% of TIC
  —Fees = 2% of TIC
- Non-Depreciable Capital
  —Start up costs = 5% of Dep. Capital
  —Working capital = 10% projected revenue

However, as mentioned previously, the level of technical and economic risk and the high capital outlay for a large facility of this type are significant barriers for investors. A smaller scale, pioneer facility would probably need to be deployed and successfully operated before these risks can be adequately addressed and before full-scale commercial facilities are viable. Details of the analysis of this pioneer plant integration into the generic refinery can be found in the final report submitted to DOE and referenced below.

In summary, the small scale pioneer plant facility suffers from economy of scale compared to the two-train coprocessing unit analyzed above with the result that the 15 percent ROE can only be realized at higher oil prices. To bridge that gap between the required selling price of coprocessed products and crude so that the investor can still realize a 15 percent return incentives would be necessary. We have analyzed the impact of two types of incentive that could be applied to this system; investment tax credits and exemption of the fuel excise tax on the coprocessed products. With no tax credit and no excise tax incentive, the ROE would be 10 percent for this plant A fuel tax exemption of about 10 cents per gallon would raise this ROE to 15 percent. A 27 percent investment tax credit would allow the investor to realize 15 percent return with no fuel tax exemption. A combination of the investment tax credit and 10 cents per gallon fuel tax exemption would realize about 22 percent return.

Considering now the case of integrating a single train, full-scale commercial coprocessing system that coprocesses Texas Lignite coal and Mexican Maya resid into the Valero Refinery. The feed to the coprocessing unit consists of 1,942 tons per day (TPD) of Texas Lignite (dry basis) and 23,604 BPD of Maya resid. The feed is a 33:67 by weight mixture of coal and resid. Data for this coprocessing case were based upon test results using the same proportions of Maya and Texas lignite conducted by Hydrocarbon Research Inc. in 1991. This data has been modified to conform to the process performance expected from operations using the HTICOPRO process.

In addition to the coprocessing unit the whole coprocessing facility includes a single train of Texaco coal gasification, gas cleaning and hydrogen separation for the production of hydrogen. Feed to this hydrogen production section consists of petroleum coke from an adjacent refinery (2,266 TPD) and CSD bottoms containing unconverted coal and unrecovered resid. This hydrogen production facility provides all of the hydrogen necessary for coprocessing (100 MMSCFD). In addition, hydrogen (47 MMSCFD) and fuel gas are sold to the refinery. The coprocessing system is sized to produce a total of 30,000 BPD of liquids and LPG. This coprocessing liquid product is sent to the Valero refinery for upgrading. The major objective in this coprocessing integration is to minimize the disruption to baseline refinery operations. This is accomplished by constraining the total volume and boiling range of feeds to the refinery units to be as similar as possible in both baseline and coprocessing cases.

Figure 3 shows schematically how the products from coprocessing are integrated into the Valero refinery and how this integration affects the feedstock inputs. Decant oil, a product from the Valero refinery, could also be used as a feedstock for coprocessing if it is less valuable than Hondo resid. Recent experimental work at HTI has demonstrated the sustainability of decant oil as a coprocessing feedstock.

Total plant construction cost for this coprocessing facility is $412 million, adding home office costs, fee, and a 12.9 percent contingency brings the total depreciable capital cost to $507 million. With the addition of start up costs and working capital, the total plant capital cost is $559 million. The operating cost for the coprocessing facility include coal at $12 per ton and pet coke at $3 per ton for a total of $10 million, catalysts and chemicals, electric power, and other that includes operating and maintenance costs. Total gross annual operating cost is $84 million. The refinery netback cost of $27 million is obtained by subtracting refinery service costs for gas processing, waste water treatment, and by-product recovery from sales revenue for hydrogen and fuel gas. Hydrogen, 47 MMSCFD, is sold to the refinery for $2 per MSCF. Net annual operating cost is therefore $57 million.

Figure 4 shows a plot of the return on equity (ROE) for this coprocessing plant for various values of oil price in dollars per gallon for two price assumptions of Maya resid and coal at $12 per ton. The ROE for this full-scale commercial unit integrated with the Valero refinery would be 15 percent with conventional 33 percent equity financing at a crude oil price of under $20 per barrel. Thus the economic viability of this full-scale coprocessing configuration is almost competitive with current oil prices. If the Maya resid can be purchased for $8 per barrel, then a 15 percent ROE can be realized at a crude oil price of between $18 and $19 per barrel. The return is also very sensitive to the price of the hydrogen sales. If hydrogen can be sold for $3 per MSCF, then a 15 percent return can be realized at about $17.50 per barrel.

The report concludes that modification of existing refineries so that are able to use a combination of coal and low value residual materials in full scale coprocessing facilities is potentially profitable at oil prices of about $18-20 per barrel. Returns on equity of about 15 percent could be realized with conventional 33 percent equity financing if the resid feed to the coprocessor was half the cost of crude oil and coal was $1 per million Btu. However, because of the high capital investment required, around $600-800 million, the uncertainties about future oil price and supply, and the technical uncertainties inherent in technology not previously proven in a commercial scale, the required modifications would not be bankable propositions for most potential investors. Smaller scale coprocessing modifications utilizing a single, half-scale coprocessing train can reduce the capital requirement to about $350M for a project supplying hydrogen for both the refinery and the coprocessing unit. These smaller units suffer from inefficiencies of scale and are thus less profitable than the full scale units. However, returns on equity in the range of 15 percent can still be realized for these pioneer plants with small incentives such as partial exemption of the federal fuels excise tax or an investment tax credit. These required incentives are significantly less costly than those that have already been provided to stimulate the production and use of other alternatives to imported oil. The successful completion of an incentivised **pioneer** plant would pave the way for full-scale follow on facilities that would be profitable without incentives. These facilities have the potential of making a substantial contribution to the production of transportation fuel from domestic sources. An important factor mitigating risk in this technology is that refinery modifications that allow coprocessing can also be used to upgrade heavy resids by themselves. It is commonly believed that in the future petroleum crude will become heavier and of lower quality so that refiners will have to upgrade refinery processes to process these future crudes.

Although this study has provided an overall assessment of the potential for this coprocessing integration, a more detailed, site specific analysis is recommended. The recommended effort would include continued research and development including bench and proof-of-concept scale tests of candidate feedstocks, conditions and catalysts, followed by a detailed preliminary design and cost estimate for the "pioneer" facility. Necessary R&D should include continued testing of coprocessing distillate products to determine their compatibility for conventional petroleum refinery processing and testing of coprocessing coke precursors to determine their suitability to produce anode grade cokes. The economic analyses would specifically identify the alternative incentive packages that would be required to produce a bankable investment package.

A final report entitled "Coal/Oil Coprocessing: Integration Opportunities with Existing Petroleum Refineries" was submitted to DOE during this quarter.

2.3) Other Activities:

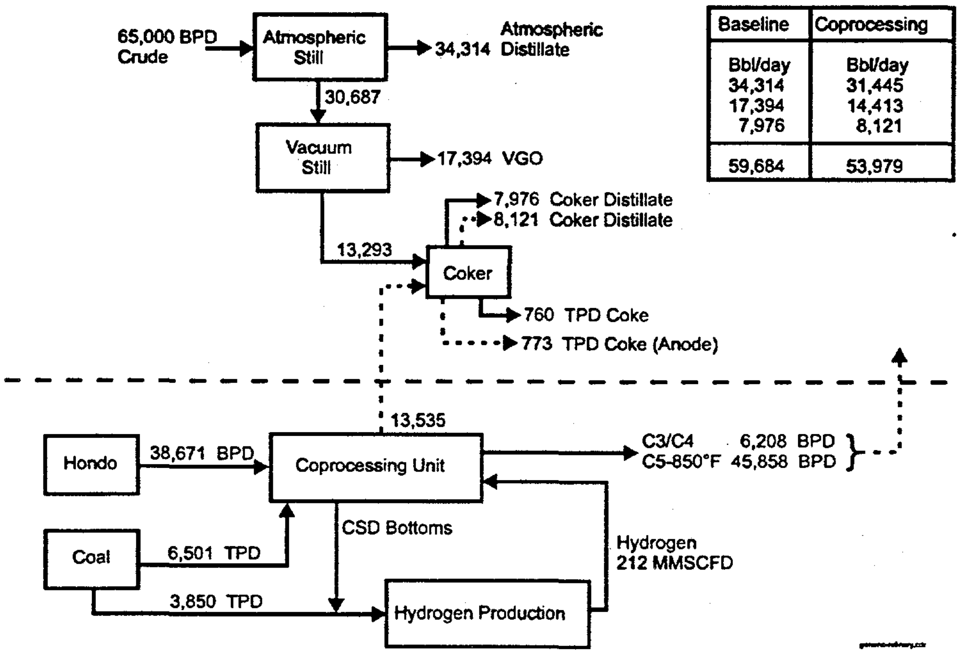
Oct 9: Mitretek personnel met with staff from HTI and DOE to discuss coal/oil coprocessing data evaluation in Lawrenceville, New Jersey.

Oct 27-31: Mitretek personnel attended and presented a paper entitled "Integration Opportunities for Coal/Oil Coprocessing with Existing Petroleum Refineries" at the Fourteenth AIST-NEDO/DOE-FETC Joint Technical Meeting on Coal Liquefaction in Tokyo, Japan.

Nov 20: Mitretek personnel attended a meeting at the Valero refining company in Houston Texas and presented an overview of the results of the Mitretek Coal/Oil Coprocessing study for integration with the Valero refinery.

Figures:

Figure 1. Generic Refinery/Two-Train Coprocessing Integration



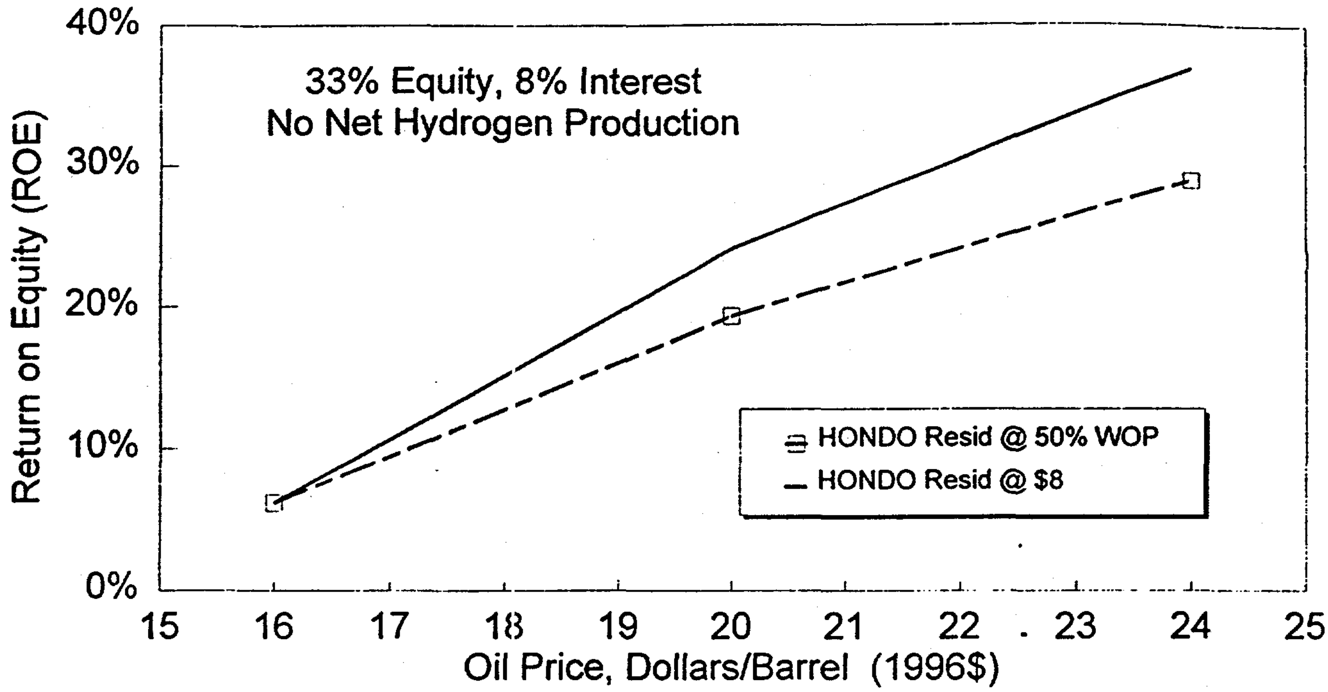


Figure 2: Impact of HONDO Price on Return on Equity
Generic Refinery With Coking, Two Train Coprocessor

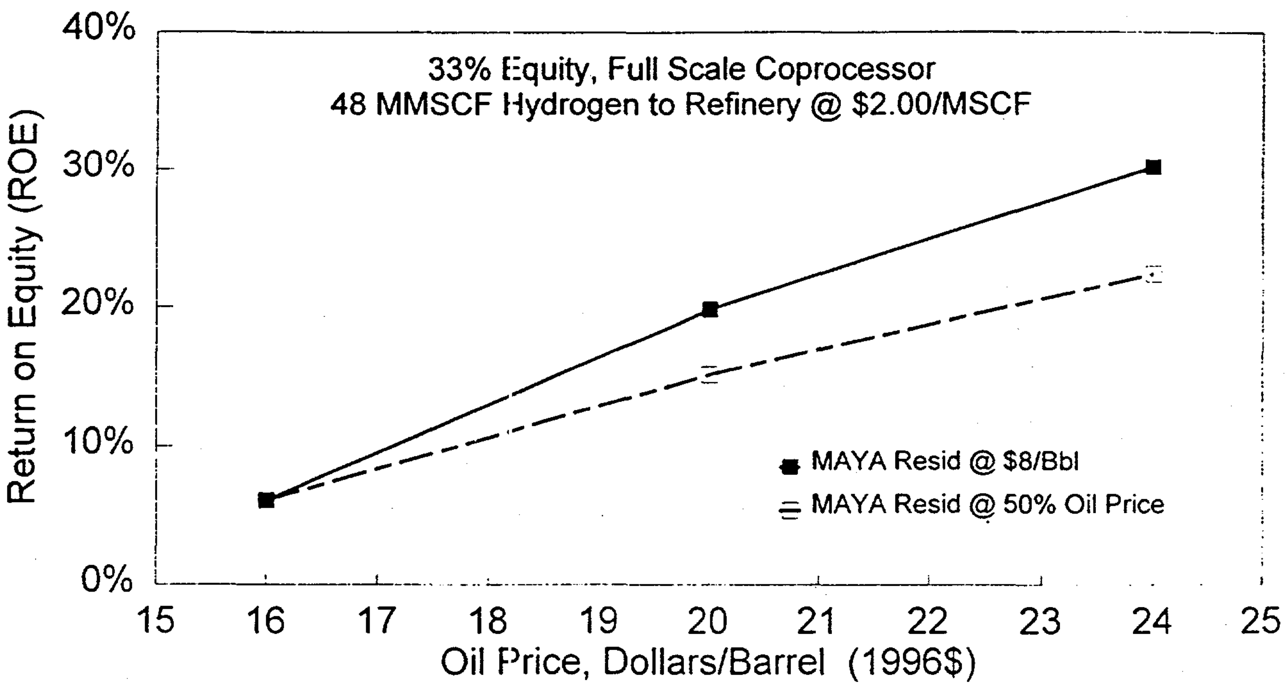


Figure 4: Return on Equity for Alternative Resid Prices
33% Texas Lignite, 67% MAYA Resid Feed

Figure 3. Overall Schematic of Valero Refinery Integrated with Single-Train, Full-Scale Coprocessing (Maya/Texas Lignite)