Wabash River Integrated Methanol and Power Production from Clean Coal Technologies (IMPPCCT)

Quarterly Technical Progress Report No. 13

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ABSTRACT

The Wabash River Integrated Methanol and Power Production from Clean Coal Technologies (IMPPCCT) project is evaluating integrated electrical power generation and methanol production through clean coal technologies. The project is conducted by a multi-industry team lead by Gasification Engineering Corporation (GEC), and supported by Air Products and Chemicals, Inc., Dow Chemical Company, Dow Corning Corporation, Methanex Corporation, and Siemens Westinghouse Power Corporation. Three project phases are planned for execution, including:

I. Feasibility study and conceptual design for an integrated demonstration facility, and for fence-line commercial embodiment plants (CEP) operated at Dow Chemical or Dow Corning chemical plant locations
II. Research, development, and testing (RD&T) to define any technology gaps or critical design and integration issues
III. Engineering design and financing plan to install an integrated commercial demonstration facility at the existing Wabash River Energy Limited (WREL) plant in West Terre Haute, Indiana.

The WREL facility is a project selected and co-funded under the Round IV of the United States Department of Energy's (DOE's) Clean Coal Technology Program. In this project, coal and/or other solid fuel feedstocks are gasified in an oxygen-blown, entrained-flow gasifier with continuous slag removal and a dry particulate removal system. The resulting product synthesis gas is used to fuel a combustion turbine generator whose exhaust is integrated with a heat recovery steam generator to drive a refurbished steam turbine generator. The gasifier uses technology initially developed by The Dow Chemical Company (the Destec Gasification Process), and now offered commercially by Global Energy, Inc., parent company of GEC and WREL, as the E-GAS™ technology.

In a joint effort with the DOE, a Cooperative Agreement was awarded under the Early Entrance Coproduction Plant (EECP) solicitation. GEC and an Industrial Consortium

are investigating the use of synthesis gas produced by the E-GAS™ technology in a coproduction environment to enhance the efficiency and productivity of solid fuel gasification combined cycle power plants.

The objectives of this effort are to determine the feasibility of an EECP located at a specific site which produces some combination of electric power (or heat), fuels, and/or chemicals from synthesis gas derived from coal, or, coal in combination with some other carbonaceous feedstock. The project's intended result is to provide the necessary technical, economic, and environmental information that will be needed to move the EECP forward to detailed design, construction, and operation by industry.

During the reporting period, effort continues on identifying potential technologies for removing contaminants from synthesis gas to the level required by methanol synthesis. A liquid phase Claus process and a direct sulfur oxidation process were evaluated. Preliminary discussion was held with interested parties on cooperating on RD&T in Phase II of the project.

Also, significant progress was made during the period in the submission of project deliverables. A meeting was held at DOE's National Energy Technology Laboratory in Morgantown between GEC and the DOE IMPPCCT Project Manager on the status of the project, and reached an agreement on the best way to wrap up Phase I and transition into the Phase II RD&T. Potential projects for the Phase II, cost, and fund availability were also discussed.

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ACRONYMS AND DEFINITIONS

Acronym	Description
ASU	Air Separation Unit
BFW	Boiler Feed-Water
CC	Combined Cycle (plant including only HRSG, CT & ST)
CEP	Commercial Embodiment Plant
CT	Combustion Turbine
CCT	Clean Coal Technologies
DOE	Department of Energy
EECP	Early Entrance Coproduction Plant
E-GAS™	Title of Global Energy, Inc.'s Gasification Process
GEC	Gasification Engineering Corporation
HHV	Higher Heating Value in Btu/SCF
HRSG	Heat Recovery Steam Generator
HTHRU	High Temperature Heat Recovery Unit
IGCC	Integrated Gasification Combined Cycle
IMPPCCT	Integrated Methanol and Power Production from Clean Coal Technologies
LGTI	Louisiana Gasification Technology Incorporated
LOX	Liquid Oxygen
LPMEOH™	Liquid Phase Methanol (process)
MAC	Main Air Compressor
MDEA	Methyl-Di-Ethanol Amine (solvent)
MeOH	Methanol
MMBtu	Million British Thermal Units
Mt	Metric Ton
MTPD	Metric Ton Per Day
MW	Mega Watt

Acronym	Description
NETL	National Energy Testing Laboratory
NOx	Oxides of Nitrogen (symbol)
NPV	Net Present Value
O&M	Operating & Maintenance
PPMV	Parts Per Million Volume
PSE	Power Systems Engineering
RD&T	Research, Development & Test (plan)
SCF	Standard Cubic Foot
SFC	Synthetic Fuels Corporation
ST	Steam Turbine
Syngas	Synthesis Gas
TPD	Tons Per Day
WBS	Work Breakdown Structure (activities)
WREL	Wabash River Energy Ltd.

1.0 BACKGROUND

1.1 E-GAS™ Process Background

The Gasification Engineering Corporation (GEC) headquartered in Houston Texas, develops and markets the E-GAS™ coal gasification process. The E-GAS™ technology is utilized at the Wabash River Energy Ltd., (WREL) facility, which is located at Cinergy's Wabash River Generating Station in West Terre Haute, Indiana. Both GEC and WREL are wholly owned subsidiaries of Global Energy, Inc., headquartered in Cincinnati Ohio.

The E-GAS™ process features an oxygen-blown, continuous-slagging, two-stage, entrained-flow gasifier, which uses natural gas for start-up. Coal or petroleum coke is milled with water in a rod-mill to form slurry. The slurry is combined with oxygen in mixer nozzles and injected into the first stage of the gasifier, which operates at approximately 2600°F and 400 psi. A turnkey, Air Liquide, 2,060-ton/day low-pressure cryogenic distillation facility that WREL owns and operates, supplies oxygen of 95% purity.

In the first stage, slurry fuel undergoes a partial oxidation reaction at temperatures high enough to bring the coal's ash above its melting point. The fluid ash falls through a taphole at the bottom of the first stage into a water quench, forming an inert vitreous slag. The synthesis gas produced by this reaction then flows to the second stage, where additional coal slurry is injected. This coal is pyrolyzed in an endothermic reaction with the hot synthesis gas to enhance the heating value of the synthesis gas and to improve the overall efficiency of the process.

The synthesis gas then flows to the high-temperature heat-recovery unit (HTHRU), essentially a fire tube steam generator, to produce high-pressure saturated steam. After cooling in the HTHRU, particulates in the synthesis gas called char are removed in a hot/dry filter and recycled to the gasifier where the carbon content in the char is converted into synthesis gas. The synthesis gas is further cooled in a series of heat exchangers, is water scrubbed to remove the chloride, and is passed through a catalyst, which hydrolyzes carbonyl sulfide into hydrogen sulfide. Hydrogen sulfide is removed from the synthesis gas using a methyl-di-ethanol-based amine solvent in an absorber/stripper column process. The "sweet" synthesis gas is then moisturized, preheated, and piped over to the power block.

The key elements of the power block are the General Electric MS 7001 FA (GE 7 FA) high-temperature combustion turbine/generator, the heat recovery steam generator (HRSG), and the repowered steam turbine. The GE 7 FA is a dual-fuel turbine (synthesis gas for operations and No. 2 fuel oil for startup) that is capable of generating a nominal 192 MW when firing synthesis gas, about seven percent (7%) higher power production than the same turbine fired on natural gas. The enhanced power production is attributed to the increased mass flows associated with synthesis gas. Steam injection is used for control of nitrogen oxides called NOx within the combustion turbine. The required steam flow is minimal compared to that of conventional systems as the synthesis gas is moisturized at the gasification facility, by recovery of low-level heat in the process. The water consumed in this process is continuously made up at the power block by water treatment systems, which clarify and further treat river water.

The HRSG for this project is a single-drum design capable of superheating 754,000 lb/hr of high-pressure steam at 1010°F, and 600,820 lb/hr of reheat steam at 1010°F when operating on design-basis synthesis gas. The HRSG configuration was specifically optimized to utilize both the gas-turbine exhaust energy and the heat energy made available in the gasification process. The nature of the gasification process in combination with the need for strict temperature and pressure control of the steam turbine led to a great deal of creative integration between the HRSG and the gasification facility. The repowered steam turbine produces 104 MW, which combines with the combustion turbine generator's 192 MW and the system's auxiliary load of approximately 34 MW to yield 262 MW (net) to the Cinergy grid.

The Air Separation Unit (ASU) provides oxygen and nitrogen for use in the gasification process but is not an integral part of the plant thermal balance. The ASU uses services such as cooling water and steam from the gasification facilities and is operated from the gasification plant control room.

The gasification facility produces two commercial by-products during operation. Sulfur, which is ultimately removed as 99.99 percent pure elemental sulfur, is marketed to sulfur users. Slag is targeted as an aggregate in asphalt roads and as structural fill in various types of construction applications. In fact, the roads at the WREL facility have been top-coated with asphalt incorporating slag as the aggregate. Furthermore, at least two surrounding area sites have been audited, approved, and have used WREL generated slag as structural fill under the Solid Waste Management Rules of Indiana. Another beneficial use of the slag by-product is as a fluxing agent during petroleum coke operation as this feed is typically deficient in mineral content required for proper slag fusion and flow. For this use, WREL has retained a reserve supply of slag generated from coal gasification.

The E-GAS™ process flow diagram presented in Figure 1.1.1 illustrates the features and components described in the above text. In Table 1.1.1, the WREL production statistics during the demonstration period of the Clean Coal Technology Program are presented in both English and Metric units. In Table 1.1.2, the WREL thermal performance variables are compared to the process design basis for both coal and petroleum coke feedstocks.

Please refer to the listing in Section 8.1 of this report for additional information on the Wabash River Coal Gasification Plant.

Figure 1.1.1: E-GAS™ Process Flow Diagram

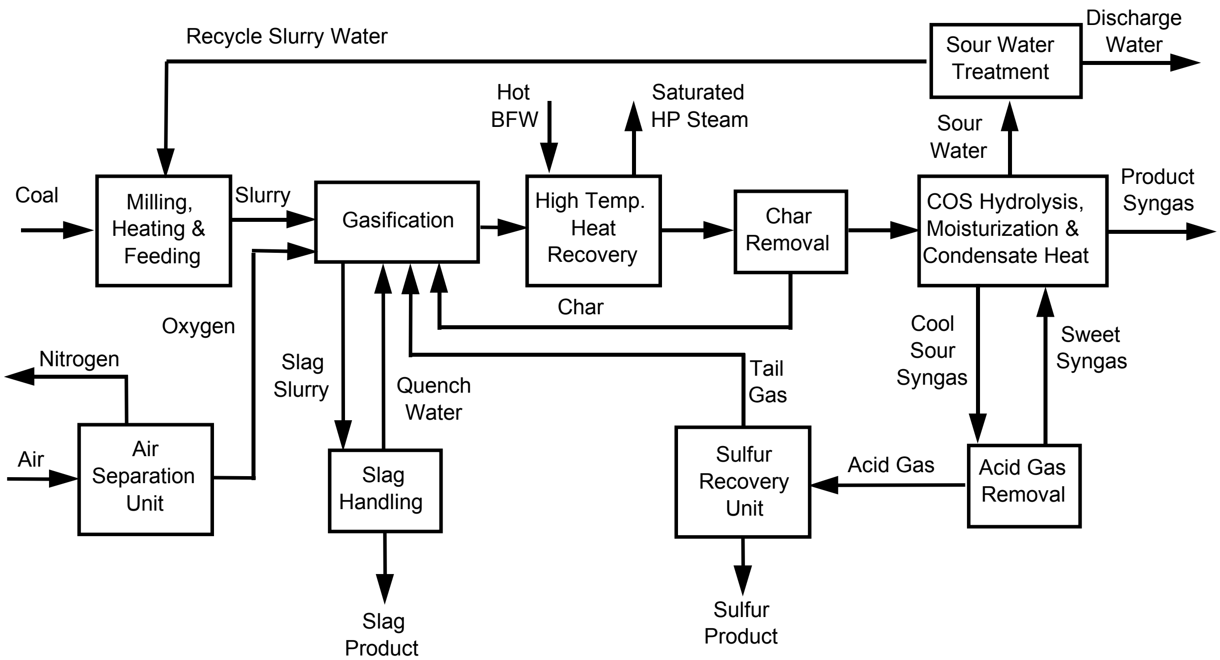


Table 1.1.1 - WREL Gasification Production Statistics during the Demonstration Period of the Clean Coal Technology Program

Production Variable	Production Year				
	1996	1997	1998	1999	2000
Gasifier Operation, Hrs	1,902	3,885	5,279	3,496*	3,406**
Dry Synthesis Gas Produced, GJ (MMBtu)	2,922,015 (2,769,683)	6,555,626 (6,213,864)	9,316,716 (8,831,011)	6,132,874 (5,813,151)	5,497,588 (5,210,984)
Coal Processed, Mt (Tons)	167,270 (184,381)	356,368 (392,822)	500,316 (551,495)	335,538 (369,862)	290,034 (319,703)
Longest Operating Campaign, (days)	19	46	82	60	104

* Three months of production were lost to the GE 7FA compressor failure & repair.
** Three months of production were lost during commercial negotiations required when the WREL Facility transitioned to market-based operation.

Table 1.1.2: Overall Thermal Performance of Gasification at WREL

Performance Feature	Design	Actual Performance	
		Coal	Coke
Nominal Throughput, TPD	2550	2450	2000
Synthesis gas Capacity, MMBtu/hr	1780	1690[†]	1690[†]
Combustion Turbine, MW	192	192	192
Steam Turbine, MW	105	96	96
Aux. Power, MW	35	36	36
Net Generation, MW	262	261	261
Plant Efficiency, % (HHV)	37.8	39.7	40.2
Sulfur Removal Efficiency, %	>98	>99	>99

[†] Synthesis gas capacity referenced for coal and petroleum coke are the actual quantities fed to the combustion turbine when 192 MW (100%) of power generation occurs.

1.2 EECP Background Information

The request for Cooperative Agreement Proposals under the "Early Entrance Coproduction Plant (EECP)," Solicitation Number DE-SC26-99FT40040 was issued on February 17, 1999, by the United States Department of Energy.

The objective of this effort is to determine the feasibility of an EECP located at a specific site which produces some combination of electric power (or heat), fuels, and/or chemicals from synthesis gas derived from coal, or, coal in combination with some other carbonaceous feedstock. The scope of this effort includes:

a. Market analysis to define site-specific product requirements (i.e. products needed by market, market size, and price), process financials, feedstock availability, and feedstock cost;

b. System analysis to define feedstocks, feedstock preparation, conversion to synthesis gas, synthesis gas cleanup, and conversion of synthesis gas to market-identified products;
c. Preliminary engineering design of the EECP facility;
d. Preparation of a research, development, and testing (RD&T) plan that addresses the technical uncertainties associated with eventual design, construction, and operation of the EECP;
e. Implementation of RD&T Plan;
f. Revision of the preliminary engineering design; and
g. Preparation of a project financing prospectus for obtaining private sector funding to perform the detailed design, construction, and operation of the EECP.

Efforts under Solicitation No. DE-SC26-99FT40040 must support an EECP that at a minimum:

1. Is a single-train facility of sufficient size to permit scaling to commercial size with minimal technical risk;
2. Provides the capability of processing multiple feedstocks (must be capable of processing coal) and producing more than one product;
3. Is undertaken by an industrial consortium;
4. Reduces risk such that future coproduction plants may be deployed with no government assistance; and
5. Meets or exceeds environmental requirements and discusses the issue of carbon dioxide reduction by one or more routes, which include mitigation, utilization, and sequestration.

Using a focused RD&T Plan, the EECP Project will enhance the development and commercial acceptance of coproduction technology that produces high-value products, particularly those that are critical to our domestic chemical, fuel, and power requirements. The proposed project will resolve critical knowledge and technology gaps on the integration of gasification and downstream processing to coproduce some combination of power, fuels and/or chemicals from coal or coal in combination with other carbonaceous feedstocks. The project's intended result is to provide the necessary technical, financial, and environmental information that will be needed to move the EECP forward to detailed design, construction, and operation by industry.

2.0 INTRODUCTION

The Wabash River Integrated Methanol and Power Production from Clean Coal Technologies (IMPPCCT) project is a $4.92 million cooperative agreement between the United States Department of Energy (DOE) and the Gasification Engineering Corporation (GEC) to evaluate the integration of gasification-based electrical generation and methanol production processes to determine the economic and technical feasibility of power/chemicals coproduction. A multi-industry team led by GEC and consisting of Air Products & Chemicals, Inc., Dow Chemical Company, Dow Corning Corporation, Methanex Corporation, and Siemens Westinghouse Power Corporation will perform the IMPPCCT study.

The consortium for the Wabash River IMPPCCT plans to analyze and develop a concept of methanol and power production based on GEC's E-GAS™ Gasification Process utilizing coal and other feedstocks. In a planned three-phase project, this team plans to review and fully analyze the domestic methanol market, examine the criteria needed and develop a robust financial model to study the economics of full-scale implementation of this gasification to power and methanol coproduction concept. Potential Dow Chemical and Dow Corning sites for the Commercial Embodiment Plant (CEP) will be examined. Feasibility studies, testing and engineering, and financing of IMPPCCT based on addition of methanol production facilities at the Wabash River Energy Limited (WREL) Gasification Plant in West Terre Haute, Indiana will be developed to enable the commercialization of the gasification to power and methanol coproduction concept.

The vision of this project is to demonstrate the commercial viability of producing electric power, process energy (steam), and chemicals (methanol) from coal and other hydrocarbon feedstocks to satisfy the demands of at least two types and corresponding sizes of host chemical complexes. An efficient, low capital, integrated facility will convert the feedstock initially to synthesis gas and ultimately to electric power, process energy, and methanol with a series of reliable, commercially-proven, and environmentally-sound unit operations. The chemical products, required process energy, and at least a portion of the electric power will be delivered to the host chemical complex for further conversion to higher value products. Any products in excess of the requirements of the host chemical complex will be sold through readily accessible distribution networks. The CEP will be technically verified from the IMPPCCT demonstration and commercially verified by an economic model and a project financing prospectus.

3.0 EXECUTIVE SUMMARY

The Wabash River Repowering project, a joint effort between Wabash River Energy Limited (WREL) and Cinergy, was selected and co-funded under Round IV of the United States Department of Energy's (DOE's) Clean Coal Technology Program. In this project, coal and/or other solid fuel feedstocks are gasified in an oxygen-blown, entrained-flow gasifier with continuous slag removal and a dry particulate removal system. The resulting product synthesis gas is used to fuel a combustion turbine generator whose exhaust is integrated with a heat recovery steam generator to drive a refurbished steam turbine generator. The gasifier uses technology initially developed by The Dow Chemical Company (the Destec Gasification Process), and now offered commercially by Global Energy, Inc., the parent company of WREL and Gasification Engineering Corporation (GEC), as the E-GAS™ technology.

The project demonstration was completed in December 1999, having achieved all of its objectives. The facility built for this project is located at Cinergy Corporation's Wabash River Generating Station near West Terre Haute, Indiana.

The Wabash Repowering project successfully demonstrated commercial application of the E-GAS™ coal gasification technology in conjunction with power generation. The combustion turbine generates 192 MW while the repowered steam turbine generates 104 MW. With the system's parasitic load of 34 MW, net power production is 262 MW, which meets the target goal. By the end of the demonstration period of the Clean Coal Technology Program, operating time had exceeded 18,000 hours, with over 5 million MW of power produced. The Wabash facility operates successfully on baseload dispatch in the Cinergy power grid, and continues to operate as a privately owned facility after the demonstration period to supply synthesis gas to Cinergy.

Gasification is an environmentally superior means of utilizing domestic coal resources for power production. It also offers the opportunity to use lower quality, less expensive feedstocks such as petroleum coke. Petroleum coke operation was successfully tested at WREL as early as November 1997. Since August 2000, the facility has been operating on 100% petroleum coke feed. As of October 2002, over 700,000 tons of petroleum coke has been processed, demonstrating the commercial viability of petroleum coke as the principle fuel for gasification.

Sulfur removal from the gasifier's solid feed is recovered and sold, as is the slag byproduct. Sulfur removal exceeds 97% resulting in SO_X emissions of 0.1 lb/million Btu, which is far below regulatory requirements of 1.2 lb/million Btu. Particulate emissions are less than the detectible limit and NOx emissions are 0.15 lb/million Btu, which meets the current target for coal-fired power generation plants. The WREL facility is the cleanest solid fuel based power plants in the world.

In a joint effort with DOE, a Cooperative Agreement titled "Integrated Methanol and Power Production from Clean Coal Technologies" (IMPPCCT), was awarded under the Early Entrance Coproduction Plant (EECP). An Industrial Consortium led by GEC and supported by Air Products, Dow Chemical, Dow Corning, Methanex, and Siemens Westinghouse is investigating the use of synthesis gas produced by the E-GAS™ technology in a coproduction environment to enhance the efficiency and productivity of solid fuel gasification combined cycle plants.

The objective of this effort is to determine the feasibility of an EECP located at a specific site which produces some combination of electric power (or heat), fuels, and/or chemicals from synthesis gas derived from coal, or, coal in combination with some other carbonaceous feedstock. The sites chosen are the existing WREL facility and greenfield locations within the Dow Chemical and Dow Corning manufacturing complexes. The project's intended result is to provide the necessary technical, financial, and environmental information that will be needed to move the EECP forward to detailed design, construction, and operation by industry.

During the reporting period, effort continues on identifying potential technologies for removing contaminants from synthesis gas to the level required by methanol synthesis. A liquid Claus sulfur removal process was evaluated and determined to be no better than optimized Methyl-Di-Ethanol Amine (MDEA) technology due to its inability to remove carbonyl sulfide (COS) and mercaptans, as well as high operating cost resulting from solvent loss. However, when the liquid Claus process is coupled with a novel direct sulfur oxidation technology, the resultant process may have potential in simplifying and lowering the cost of a conventional IGCC process, and therefore enhance a CEP IMPPCCT project.

Preliminary discussion was held with interested parties on cooperating on RD&T Phase of the project. Feedback from the technology suppliers were very enthusiastic. Small-scale slipstream testing at WREL, using actual synthesis gas being produced, is the preferred mode of testing. The effort would be supplemented with laboratory testing to identify the optimum operating condition, and to resolve problems identified during the slipstream testing. Most of the technology suppliers appear to be receptive to providing the 35% cost-sharing required in the Phase II.

Also, significant progress was made during the period in the submission of project deliverables. A meeting was held at DOE's National Energy Technology Laboratory (NETL) in Morgantown between GEC and the DOE IMPPCCT Project Manager on the status of the project, and the best way to wrap up Phase I and transition into the Phase II RD&T. Potential projects for the Phase II, cost, and fund availability were also discussed.

For the period of reporting, actual expenditure for the reporting period was $24,186, with cumulative actual expenditure for the project to be $824,794. The amounts include funding from DOE that is at 80% of the total, and cost share provided by the consortium members. The figures are a reflection of actual invoice totals to the DOE and are current for the period of report issue. Total budget for the project is $1,933,628, with DOE providing $1,546,902.

4.0 ACTIVITIES

4.1 Synthesis gas Contaminant Removal

During this period, review of methods for the removal of contaminants from the product synthesis gas continued. Investigation of the liquid phase Claus process initiated in the previous reporting period progressed into further details. A novel gas phase direct sulfur oxidation process was also investigated.

4.1.1 Novel Liquid Phase Claus Process

The liquid phase Claus direct sulfur removal process being commercialized for removing low levels of hydrogen sulfide from natural gas discussed in the previous reporting period was further investigated for polishing the synthesis gas in the IMPPCCT Project. Initial study showed some promise. More detailed information on the process and capital and operating costs were obtained for evaluation. The process could be commercially available in the time frame needed for both the WREL and the CEP IMPPCCT.

4.1.2 Novel Direct Sulfur Oxidation Process

A direct sulfur oxidation process under development was also investigated. The process, when coupled with a sulfur scavenging system such as the liquid phase Claus process investigated in 4.1.1, has the potential to replace the COS hydrolysis, acid gas removal, and sulfur conversion systems. If the process is successful, the impact on the capital and operating costs for a new grass-roots CEP plant could be significant. A preliminary laboratory test on the direct sulfur oxidation step was conducted by the research laboratory at the request of GEC and at no cost to the IMPPCT Project.

4.2 Planning for Phase II RD&T

GEC initiated preliminary discussion with companies to gauge their interest in conducting testing in the Phase II RD&T of the project. The types of testing were also discussed. The main area being pursued is in synthesis gas contaminant removal.

Potential testing projects include the regenerable activated carbon and the liquid phase Claus in conjunction with the direct sulfur oxidation process.

4.3 Reporting and Deliverables

During this reporting period, significant effort was made to revise and close out some of the previous Quarterly Technical Progress Reports that were returned from DOE for additional comments and corrections.

A meeting was held at NETL in Morgantown on November 5 between GEC and the DOE IMPPCCT Project Manager on the status of the project, and the best way to wrap up Phase I and transition into the Phase II RD&T. Potential projects for the Phase II, cost, and fund availability were also discussed.

5.0 RESULTS AND DISCUSSION

The consortium for the Wabash River IMPPCCT, led by GEC, and including Dow Corning, Dow Chemical, Air Products, Methanex, and Siemens Westinghouse, continued to analyze and develop a concept of methanol and power production based on GEC's E-GAS^{TM} Gasification Process utilizing coal and petroleum coke feedstocks. The team furthered efforts to analyze the domestic methanol market and examined other criteria needed to develop an economic model for full-scale implementation of this gasification to power and methanol coproduction concept. Feasibility studies, testing and engineering, and financing of an IMPPCCT facility based on addition of methanol production capabilities at the WREL gasification plant in West Terre Haute, Indiana will be developed to enable the commercialization of the gasification to power and methanol coproduction concept.

5.1 Synthesis gas Contaminant Removal

During this period, review of methods for the removal of contaminants from the product synthesis gas continued. Investigation of the liquid phase Claus process initiated in the previous reporting period progressed into further details. A novel gas phase direct sulfur oxidation process was also investigated.

5.1.1 Novel Liquid Phase Claus Process

A recently developed acid gas removal process, CrystaSulf^{TM}, developed by CrystaTech, Inc. for removing low levels of hydrogen sulfide for natural gas application was evaluated for applicability to the IMPPCCT Project. The process is similar to aqueous iron chelate reduction-oxidation processes that convert hydrogen sulfide (H_2S) directly to elemental sulfur. However, CrystaSulf^{TM} uses a proprietary high-boiling hydrocarbon-based organic solution that does not have the problems, such as foaming and plugging of the equipment by sulfur deposits, encountered in the aqueous iron chelate systems. The organic solution acts only as the carrier and does not take part in the direct sulfur conversion reaction. Therefore it does not have to be regenerated after the elemental sulfur formed is removed from the solution. The solution can also tolerate high carbon dioxide concentrations in the feed gas such as in the IMPPCCT synthesis gas, whereas in the aqueous iron chelate systems, sodium bicarbonate precipitates are formed with the carbon dioxide. The process has been pilot tested for natural gas applications. A commercial-scale plant is being started up in a West Texas natural gas production site. However, the CrystaSulf^{TM} process cannot reduce the H_2S to less than 4 ppmv. Also, the process does not remove COS or mercaptans. Therefore it does not have any advantage over an optimized MDEA system in replacing a MDEA system, nor could it be used downstream of a MDEA system for polishing the residual sulfur to the level required by methanol synthesis.

An order of magnitude cost estimate for a CrystaSulf^{TM} system for WREL would be $5-7 million, plus the cost of a zinc oxide guard bed. The drawback for the CrystaSulf^{TM} system, other than its inability to remove COS, is its high operating cost, likely in the multi-million-dollars per year range, in replenishing the expensive solvent lost through evaporation and degradation. The system as is does not have any advantage over an optimized MDEA system.

5.1.2 Novel Direct Sulfur Oxidation Process

A recent development of the CrystaSulf^{TM} process to incorporate a H_2S catalytic oxidation process developed by TDA Research, Inc. to form the DirectSulf^{TM} process may offer a novel approach to acid gas removal for gasification applications. The TDA process is also being developed for natural gas purification under DOE funding. A stoichiometric amount of oxygen (O_2) is injected into the process gas stream that contains H_2S. Sulfur species, including COS and mercaptans, are converted to elemental sulfur or sulfur dioxide (SO_2) at a temperature range of 350-500°F. Selectivity to elemental sulfur or SO_2 can be controlled by the choice of catalyst and the amount of O_2 injected. Up to 90% of the H_2S could be converted. The CrystaSulf^{TM} process could then remove the sulfur, H_2S, and SO_2 as elemental sulfur, at the same time reducing the sulfur concentration in the gas stream to 4 ppmv. Such a process, if proven successful, could replace the COS hydrolysis, acid gas removal, and sulfur conversion systems in a conventional gasification process. The capital savings could be significant, with a positive impact on a grass-roots IMPPCCT facility such as the CEP. Since WREL is already built, this process would not be applicable to the WREL IMPPCCT Project. No economic comparison of the DirectSulf^{TM} process has been conducted yet because of the lack of data from such a process, especially for a gasification application.

So far most of the TDA investigation has been for natural gas applications. However, a test run was conducted recently, at the request of GEC, in their laboratroy-scale reactor with a simulated synthesis gas stream. The test was conducted at no cost to the IMPPCCT Project. The purpose of the test was to determine if the oxygen injected would react with the hydrogen (H_2) or carbon monoxide (CO) instead of H_2S in the synthesis gas. A gas stream blended with 2% of CO, 2% H_2, 2000 ppmv of H_2S, and 1500 ppmv of O_2 was passed over a catalyst at 355°F. Close to 90% of the H_2S was converted while the H_2 and CO did not react with the O_2.

The DirectSulf^{TM} process, because of the use of the CrystaSulf^{TM} liquid Claus system, would still require a sulfur polishing system, such as a zinc oxide sacrificial guard bed, to remove sulfur contaminants to the level required by methanol synthesis. Since the COS and mercaptans are removed in this case compared to the CrystaSulf^{TM}–only case, the total residual sulfur is less, and therefore a longer lasting and lower cost for the guard bed.

Initial information of the DirectSulf^{TM} process looks promising and justifies further investigation and testing. Since the process is already in the pilot plant stage for natural gas applications, it could be commercially available for gasification applications in the timeframe needed for the CEP IMPPCCT.

5.2 Planning for Phase II RD&T

GEC initiated preliminary discussion with companies to gauge their interest in conducting testing in the Phase II RD&T of the project. The types of testing were also discussed. The main area being pursued is in synthesis gas contaminant removal. Potential testing projects include the regenerable activated carbon system previously investigated and the DirectSulf™ (liquid phase Claus in conjunction with the direct sulfur oxidation) process.

Feedback from the technology suppliers was found to be very enthusiastic. Small-scale slipstream testing at WREL, using actual synthesis gas being produced, is the preferred mode of testing. Laboratory testing will be conducted prior to the on-site slipstream testing to narrow the optimum operating condition for the slipstream unit. Additional laboratory testing could be done after the slipstream test if specific problems were identified during the slipstream testing that need to be resolved.

Most of the technology suppliers seem to be receptive to providing the 35% cost-sharing required in the Phase II.

5.3 Reporting and Deliverables

During this reporting period, significant progress was made to revise and close out some of the previous Quarterly Technical Progress Reports that were returned from DOE for additional comments and corrections. Revisions to Quarterly Technical Progress Reports No. 1 to 6 for the period of October 1, 1999 to March 31, 2001 were made and sent to DOE for final approval.

A meeting was held at NETL in Morgantown on November 5, 2002 between GEC and the DOE IMPPCCT Project Manager on the status of the project, and the best way to wrap up Phase I and transition into the Phase II RD&T. Because of the diminishing interest in some of the participants in the Consortium due to the marginal economics of the project, it was not possible to get their commitment to furnish all the necessary information or their cooperation to finish up all the deliverables in the proper manner. At the same time, there are new and interesting technologies identified in the Phase I feasibility study that, if successful, could bridge the technology gaps and improve the economics in the IMPPCCT Project. It was mutually agreed between GEC and the DOE Project Manager that GEC should prepare a formal RD&T Plan for submittal to DOE, identifying the RD&T projects that should be conducted in the Phase II and a proposal for each of the projects. The remaining deliverables, including the Initial Feasibility Report, Concept Report, Site Analysis Report, Economic Analysis, and Preliminary Project Financing Plan, would be combined into one comprehensive Final Report for Phase I of the project.

6.0 CONCLUSIONS

Under the guidance of the Project Management Plan, Phase I is being performed by all team members, GEC, Air Products, Methanex, Dow Corning, Siemens Westinghouse, and Dow Chemical. The Phase I focus is on development of the advanced economic model, analysis of the commercialization potential for the gasification to methanol and power coproduction concept for future CEP, and preliminary engineering and environmental work for implementation of the methanol production addition at Wabash River for the IMPPCCT demonstration. GEC has utilized the analysis of potential IMPPCCT feedstocks to the gasification section, developed a preliminary site layout, determined synthesis gas quantities available to IMPPCCT, assessed final synthesis gas cleanup needs, provided the preliminary environmental assessment, reviewed modifications and tie-ins to the existing infrastructure at the WREL site, and worked jointly with Air Products and Methanex to develop the most advantageous economics for IMPPCCT based on either the liquid or gas phase methanol processing units. Air Products has completed the review and application of the LPMEOH™ Process with methanol purification systems resulting in development of the methanol unit process package.

6.1 Synthesis gas Contaminant Removal

Efforts to identify processes for polishing the synthesis gas in the IMPPCCT Project to level required for methanol synthesis continued. The CrystaSulf™ liquid phase sulfur conversion process being commercialized for removing low levels of hydrogen sulfide from natural gas does not remove COS or mercaptans, nor reduce the hydrogen sulfide to low enough level for methanol synthesis. CrystaSulf™'s high operating cost, likely in the multi-million-dollars per year range, in replenishing the expensive solvent lost through evaporation and degradation, is another drawback. The system, as is, does not have any advantage in replacing a MDEA system, nor used downstream of a MDEA system for polishing the residual sulfur to the level required by methanol synthesis.

When CrystaSulf™ is coupled with a novel direct sulfur oxidation process under development, together called the DirectSulf™ process, the combined process looks much more attractive. The direct sulfur oxidation process converts all sulfur contaminants including H_2S, COS, and mercaptans to elemental sulfur. As a result, the total residual sulfur in the product synthesis gas is much lower, and a sacrificial guard bed would be more affordable. Such a process, if proven successful, could replace the COS hydrolysis, acid gas removal, and sulfur conversion systems in a conventional gasification process. The capital savings could be significant, with a positive impact on a grass-roots IMPPCCT facility such as the CEP. Results from a test in a laboratory-scale reactor with a simulated synthesis gas stream, conducted at the request of GEC at no cost to the IMPPCCT Project, were very encouraging. Further investigation of this combined process will continue.

6.2 Planning for Phase II RD&T

GEC initiated preliminary discussion with technology suppliers to gauge their interest in conducting testing in the Phase II RD&T of the project. The main area being pursued is in synthesis gas contaminant removal. Potential testing projects include the regenerable activated carbon previously investigated and the liquid phase Claus in conjunction with the direct sulfur oxidation process.

Feedback from the technology suppliers was very enthusiastic. Small-scale slipstream testing at WREL, using actual synthesis gas being produced, is the preferred mode of testing. The effort would be supplemented with laboratory testing to identify the optimum operating condition, and to resolve problems identified during the slipstream testing.

Most of the technology suppliers seem to be receptive to providing the 35% cost-sharing required in the Phase II.

6.3 Reporting and Deliverables

Significant progress was made in revising and closing out some of the Quarterly Technical Progress Reports sent back from DOE for revision and clarification. Reports No. 1 to 6 for the period of October 1, 1999 to March 31, 2001 were revised and sent to DOE for final approval.

Drafting of a Research, Development, and Test (RD&T) Plan has started.

7.0 MILESTONES & PLANS

7.1 Plans for Next Reporting Period

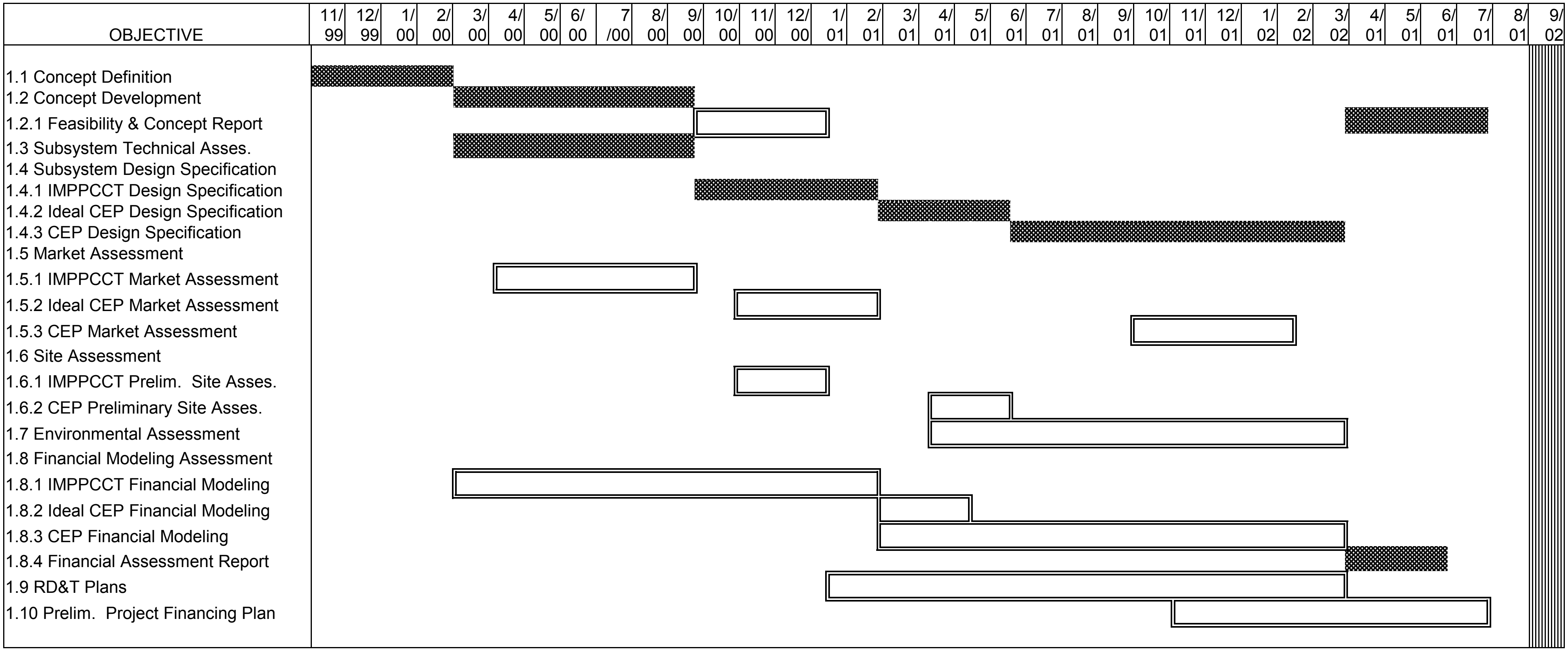
Efforts during the next reporting period are expected to primarily concentrate on reporting requirements, to complete all the Quarterly Technical Progress Reports and the RD&T Plan. The Initial Feasibility Report, Concept Report, Site Analysis Report, Economic Analysis, and Preliminary Project Financing Plan would be combined and consolidated into one comprehensive Phase I Final Report.

7.2 Project Schedule and Milestones

Figure 7.2.1 illustrates the original Phase I project milestone map. The blocks shown in full shading are those associated with the critical path to completion of Phase I. Hollow blocks are tasks which support the overall time table and/or result in deliverable items to the DOE. Due to continued resource allocation related issues, implementation of the project is behind schedule. This schedule does not reflect the extension of the project to February 2003 granted GEC during a previous reporting period.

During the reporting period, the project made significant progress on reporting efforts for the Phase I study. Most of the continuing efforts in Phase I will be devoted to completing all the reporting requirement, including a RD&T Plan and a consolidated Final Report.

Figure 7.2.1 : Phase I, IMPPCCT Milestones



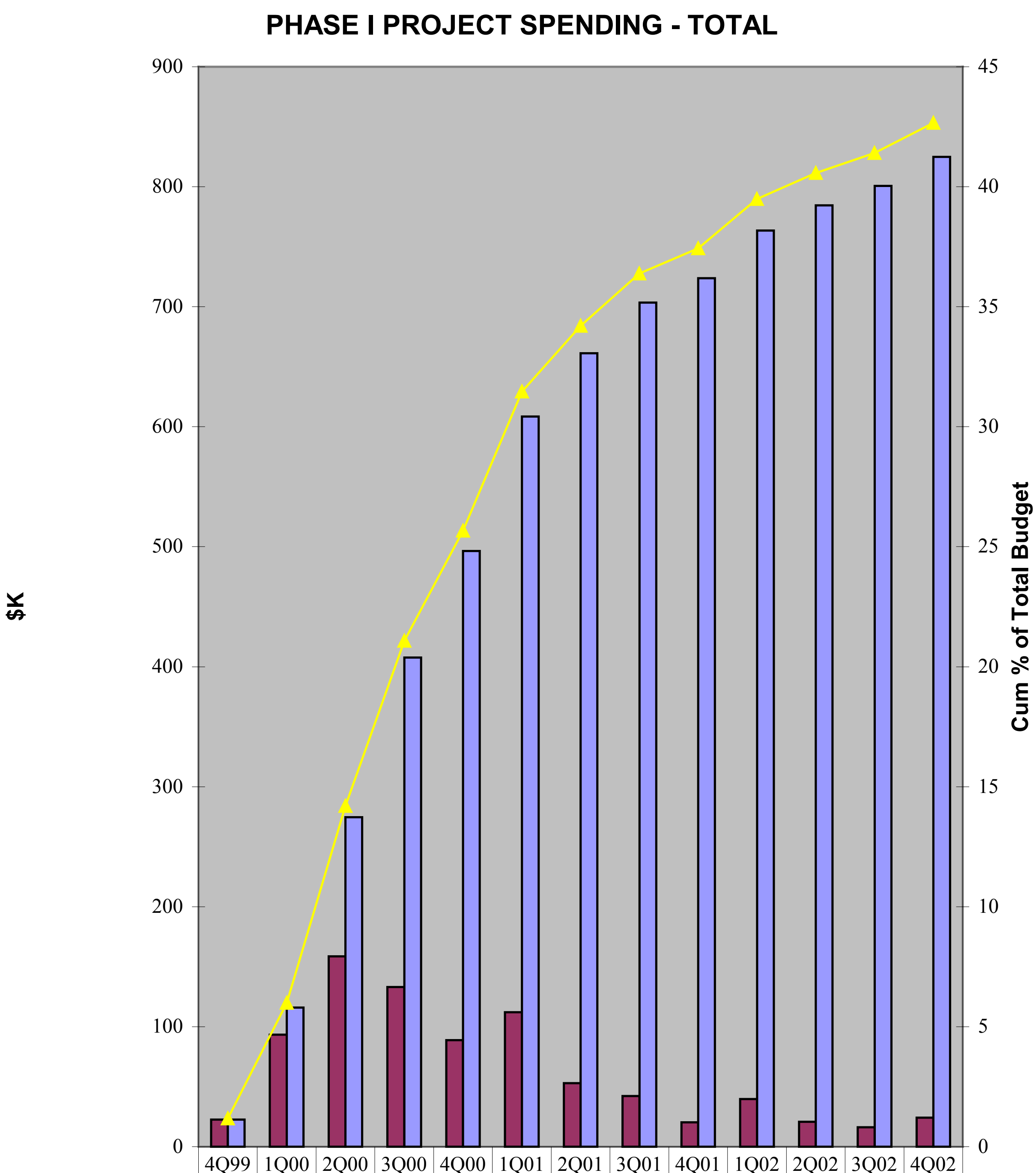
(Solid blocks are critical path)

7.3 Project Spending -- Plan and Actuals

As shown in Figure 7.3.1, actual expenditure for the reporting period was $24,186, with cumulative actual expenditure for the project to be $824,794. The amounts shown over the periods of the graphs are based on actual invoice figures to the DOE. The figures include funding from DOE that is at 80% of the total, and cost share provided by the consortium members. Total budget for the project is $1,933,628, with DOE providing $1,546,902.

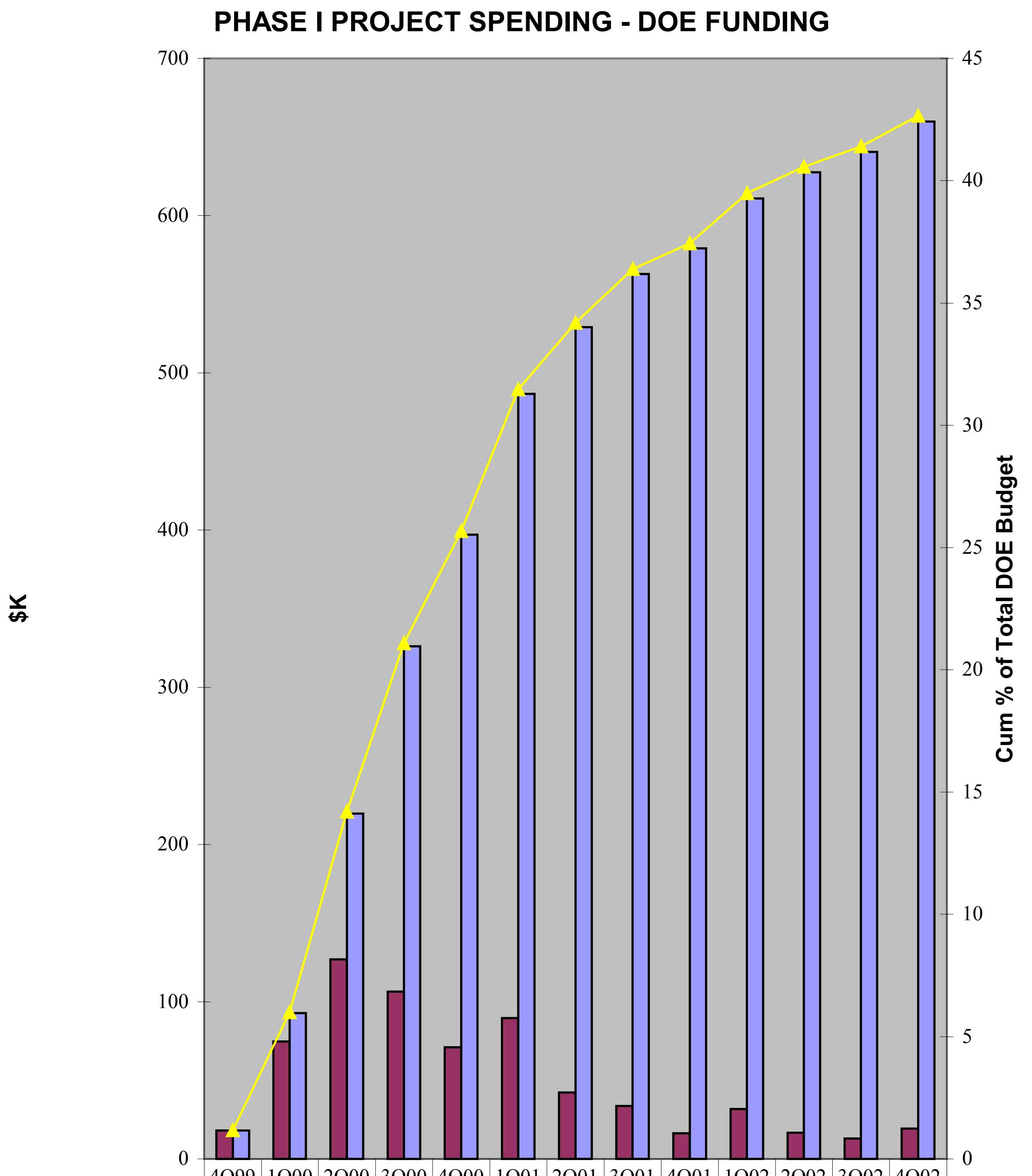
Figure 7.3.1 and Figure 7.3.2 present the actual total spending and spending of DOE cost share respectively for the IMPPCCT Phase I effort. Current spending pattern is far below plan.

Figure 7.3.1: Phase I Project Spending -- Overall



	4Q99	1Q00	2Q00	3Q00	4Q00	1Q01	2Q01	3Q01	4Q01	1Q02	2Q02	3Q02	4Q02
$K Spent	22.6	93.3	158.6	133.1	88.7	112.1	52.9	42.1	20.4	39.7	20.8	16.2	24.2
$K Cum	22.6	115.9	274.5	407.7	496.4	608.5	661.4	703.5	723.9	763.6	784.4	800.6	824.8
Cum % Spent	1.2	6.0	14.2	21.1	25.7	31.5	34.2	36.4	37.4	39.5	40.6	41.4	42.7

Figure 7.3.2: Phase I Project Spending -- DOE Funding



	4Q99	1Q00	2Q00	3Q00	4Q00	1Q01	2Q01	3Q01	4Q01	1Q02	2Q02	3Q02	4Q02
$K Spent	18.1	74.6	126.9	106.5	71.0	89.6	42.3	33.7	16.3	31.8	16.7	12.9	19.3
$K Cum	18.1	92.7	219.6	326.1	397.1	486.8	529.1	562.8	579.1	610.9	627.6	640.5	659.8
Cum % Spent	1.2	6.0	14.2	21.1	25.7	31.5	34.2	36.4	37.4	39.5	40.6	41.4	42.7

8.0 REFERENCES

8.1 Selected References Available via the Internet

1. **"National Energy Policy", issued by the White House in May 2001.** The Wabash River facility and Global Energy received mention in a dedicated sidebar on page 3-6.
   http://www.whitehouse.gov/energy/Chapter3.pdf

2. **"Wabash River Coal Gasification Repowering Project, An Update**", Department of Energy Topical Report No. 20, September 2000, summarizes the history of the Wabash River facility and its construction and four year demonstration under the DOE's Clean Coal Technology program.
   http://www.lanl.gov/projects/cctc/topicalreports/documents/topical20.pdf

3. **"Wabash River Coal Gasification Repowering Project Final Technical Report",** August 2000, 358 pages. This is a very detailed look at the Wabash River facility and its operation 1995-1999.
   http://www.lanl.gov/projects/cctc/resources/pdfs/wabsh/Final%20_Report.pdf

4. **"Gasification Plant Performance and Cost Optimization",** May 2002, (23 MB). The final report of Task 1 of this comprehensive ($2.4 million) study performed by Global Energy, Nexant and Bechtel under subcontract to the DOE to identify cost savings in the next generation of integrated gasification and coproduction facilities utilizing the E-Gas Technology. Detailed cost estimating by Bechtel.
   http://www.netl.doe.gov/coalpower/gasification/projects/systems/docs/40342R01.PDF

5. **"Wabash River Coal Gasification Repowering Project, A DOE Assessment",** January 2002. This is the DOE's official post-project assessment of the Wabash River project.
   http://www.lanl.gov/projects/cctc/resources/pdfs/wabsh/netl1164.pdf

6. **"Environmental Benefits of Clean Coal Technologies"** Department of Energy Topical Report No. 18, April 2001. This report describes a variety of processes that are capable of meeting existing and emerging environmental regulations and competing economically in a deregulated electric power marketplace
   http://www.lanl.gov/projects/cctc/topicalreports/documents/topical18.pdf

7. **"Coproduction of Power, Fuel, and Chemicals"** Department of Energy Topical Report No. 21, September 2001. A description of the production of synthesis gas (syngas) from coal, the production of electricity from combusting a portion of the syngas and conversion of the remaining syngas to high-value fuels and chemicals.
   http://www.lanl.gov/projects/cctc/topicalreports/documents/topical21.pdf

8. **The Gasification Technology Council** maintains a website (www.gasification.org) that includes a library of the papers presented at recent conferences. Papers presented by Global Energy in 2002 & 2001:

   "Wabash River Repowering IGCC Operations and Performance Update Report", October 2002
   http://www.gasification.org/Presentations/2002_papers/GTC02010.pdf

   "Comparative IGCC Cost & performance for Domestic Coals", October 2002
   http://www.gasification.org/Presentations/2002_papers/GTC02018.pdf

   "NOx Control in IGCC Combustion Turbines: Steam vs. Nitrogen", October 2002
   http://www.gasification.org/Presentations/2002_papers/GTC02022.pdf

   "Optimized Petroleum Coke IGCC Coproduction Plant", October 2001
   http://www.gasification.org/98GTC/GTC01018.pdf

   "Environmental Performance of IGCC Repowering for Conventional Coal Power Plants", October 2001
   http://www.gasification.org/98GTC/GTC01037.pdf