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ABSTRACT

The major aspects of this project are proceeding toward completion. Prior to this quarter, design criteria, tentative site selection, facility layout, and preliminary facility cost estimates were completed and issued. Processing of bio-solids was completed, providing material for the pilot operations. Pilot facility design, equipment selection, and modification were completed during the fourth quarter of 2000. Initial pilot facility shakedown was completed. After some unavoidable delays, a suitable representative supply of MSW feed material was procured. During this first quarter of 2001, shredding of the feed material and final feed conditioning were completed. Pilot facility hydrolysis production was completed to produce lignin for co-fire testing and the lignin fuel was washed and dewatered.

Both the lignin and bio-solids fuel materials for co-fire testing were sent to the co-fire facility (EERC) for evaluation and co-firing. EERC has received coal typical of the fuel to the TVA-Colbert boilers. This material will be used at EERC as baseline material and for mixing with the bio-fuel for combustion testing. EERC combustion testing of the bio-based fuels is scheduled to begin in October of 2001.

The TVA-Colbert facility has neared completion of the task to evaluate co-location of the Masada facility on the operation of the power generation facility. The TVA-Colbert fossil plant is fully capable of providing a reliable steam supply. The preferred steam supply connection points and steam pipeline routing have been identified. The environmental review of the pipeline routing has been completed and no major impacts have been identified. Detailed assessment of steam export impacts on the Colbert boiler system have been completed and a cost estimate for steam supply system was completed. The cost estimate and the output and heat rate impacts will be used to determine a preliminary price for the exported steam.

REPORT NO. 00-10734/06

QUARTERLY REPORT FOR THE CONCEPTUAL DESIGN ASSESSMENT FOR THE CO-FIRING OF BIOREFINERY SUPPLIED LIGNIN PROJECT

PROJECT NO. 00-10734
MASADA DOE LIGNIN STUDY

MASADA RESOURCE GROUP, LLC
BIRMINGHAM, AL

DATE: OCTOBER 17, 2001

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1. INTRODUCTION

The development of renewable domestic fuel sources is a desirable goal with positive economic and environmental impacts. Masada Resource Group (MRG) has developed a proprietary process for the conversion of municipal solid waste (MSW) and sewage sludge (SS) into ethanol (CES OxyNol™ Process). One of the byproducts of this process is a solid lignin product. MRG has developed a method for using this MSW-derived lignin as a solid fuel for steam generation. In this joint research project, a conceptual design will be developed that joins a CES OxyNol™ facility with a Tennessee Valley Authority (TVA) coal-fired power plant (the TVA-Colbert facility).

MRG is working with Harris Group Inc. (HGI), TVA, and the Department of Energy (DOE) to develop a conceptual design for the co-firing of bio-refinery-derived lignin fuel in a coal-fired steam boiler. This project will research the dewatering and fuel properties of the CES OxyNol™-derived fuel. The project will evaluate the technological feasibility and cost/benefit analysis of co-locating a CES OxyNol™ facility with the TVA-Colbert facility. In this configuration the bio-refinery supplies boiler fuel (lignin) to the Colbert facility and the Colbert facility provides the process steam needed for the CES OxyNol™ process. The co-location has the benefit of providing a low-cost renewable biomass fuel source that can be co-fired with coal. Co-location also reduces the capital and operating costs of the CES OxyNol™ process and provides environmental gains by reducing the impact of coal combustion and providing an environmentally acceptable method for the disposal of solid waste.

This project has been divided into six separate but related tasks to reach the aforementioned goals of the project. Progress has been made on most of the specific tasks. The goal of the pilot run is both to evaluate dewatering options and to generate lignin to be used in the co-fire evaluation at the Environmental Energy Research Center (EERC). Pilot facility modification, shakedown, and lignin production were completed in preparation for the co-fire testing.

The first task is the overall feasibility analysis for co-location of the Masada facility with a TVA power facility. Task 1

- Identified facility design criteria.
- Identified potential facility locations and preliminary site layout.
- Evaluated the economic impact associated with co-location.

The second task is the assessment of the impacts on the TVA facility. TVA's Fossil Engineering Organization is performing a preliminary engineering assessment for delivering steam from the TVA-Colbert fossil plant to the proposed Masada waste processing facility. The study will identify

- Steam supply connection point in the Colbert plant steam cycle
- Steam pipe routing from the steam cycle connection to the Colbert plant boundary
- Capacity and heat rate impacts on the Colbert plant resulting from the steam supply
- Environmental review of the steam pipe installation
- Capital cost of the steam supply design, materials, and installation
- Operation and maintenance cost impacts on the Colbert plant resulting from the steam supply

This information will be used to develop a price for the steam to be supplied from the Colbert plant to the Masada facility.

Tasks 3 and 4 involved the pilot plant facility design, modification, and shakedown for the production of lignin. Pilot plant design and modification have been completed and shakedown testing of the facility was completed. Transitioning from the pilot facility shakedown phase to the operations phase was delayed due to difficulties in obtaining a representative MSW feed material.

Task 5 is the production of lignin in the TVA pilot facility. The pilot plant production operation occurred in the fourth quarter of 2000 and the first quarter of 2001. The lignin production activity has been completed. TVA processed approximately 20 batches in the hydrolysis pilot facility to generate sufficient lignin for co-fire testing. The mother liquor was filtered from the lignin and the resulting lignin was prepared for washing and dewatering.

Task 6 is lignin washing and dewatering. This process is employed to maximize the recovery of both sugar and acid from the lignin cake and to improve the characteristics of the lignin fuel. This task has largely been completed.

Task 7 is the co-fire testing of the lignin and bio-solids. In this testing of the material, the bio-fuel is combusted as a mixture with coal in a test boiler to estimate the combustion parameters and how the addition of this material to a coal-fired boiler will impact boiler operation. Both the lignin and bio-solid materials are tested in individual mixtures with coal and as a composite mixture with coal. In each case, the target mixture is a 10% bio-fuel, 90% coal blend. This blending is well above the expected blending ratio for the TVA-Colbert facility but rich enough in bio-based fuels to allow detection of potential changes and improvements in boiler operations as a result of the bio-fuel addition. This testing will be accomplished at EERC. EERC will perform a series of tests designed to evaluate the following:

- Fuel value
- Slagging and fouling
- Corrosion
- Fly ash properties
- Gas emissions
- Trace element analysis and emissions

To accomplish these objectives, EERC will perform a series of combustion tests in its combustion test facility accompanied by analysis of the fuels and combustion products. These tests include combustion of the baseline coal as well as mixtures of coal with lignin and bio-solids.

2. EXPERIMENTAL

TVA has considerable experience in the acid hydrolysis process and its experimental experience has been applied to the lignin production, washing, and dewatering. The lignin dewatering and conditioning were studied in conjunction with dewatering equipment vendors and with input from the test burn facility. The hydrolysis process used during these tests to produce lignin samples is the proprietary Masada CES OxyNoI™ process. Experimental procedures for the test burn will be standard procedures used by EERC for fuel analysis and test unit operations, as presented previously.

3. RESULTS AND DISCUSSION

3.1 General

Progress on the major tasks of this project continues. Engineering impact of the co-fire concept is favorable. TVA-Colbert completed the evaluation of steam supply options and impacts, indicating that supply options exist. A cost estimate for the system modifications has been completed. TVA pilot facility modifications have been completed. The pilot plant has completed lignin production. Some delays had occurred due to difficulty in procuring a suitable representative MSW feed supply. A feed supply was procured and lignin production completed. TVA has completed the lignin washing and dewatering aspects of this project.

NETL has expressed reservations with respect to the co-fire of the lignin/sewage sludge mixed material in the NETL test boiler. EERC has agreed to perform the co-fire portion of the testing and has indicated that co-firing of this type of material should be easily accomplished. The lignin and bio-solids co-fire feed materials have been shipped to the EERC co-fire test site for feed characterization and preparation for co-fire test runs.

3.2 Engineering Impact Analysis

During the third quarter of 2001 no significant changes were identified from the previous engineering impact analysis. The previously issued design criteria and site identification allow the TVA-Colbert power facility to complete the investigations into the impacts and facility modifications that would be required for this project. TVA-Colbert is completing an investigation of the impacts on the power plant operations. Results of the TVA-Colbert study to date are reported below in paragraph 3.6.

3.3 Pilot Facility Modification, Feed Conditioning and Hydrolysis Operations

For lignin production, TVA's pilot facility was modified for Masada's proprietary process. TVA, Lizan, and Harris worked with Masada to identify equipment needed for the lignin production pilot run. As described previously, TVA's pilot facility was set up to operate the OxyNoI™ process in a batch mode. This process included the hydrolysis of a conditioned MSW feed material to produce a lignin fuel for co-fire testing.

As discussed in previous reports, an unavoidable delay in the acquisition of a representative MSW supply caused a delay in pilot plant operations. A representative MSW supply was procured and delivered to a vendor testing facility for feed conditioning. Feed conditioning was completed and the MSW material was shipped to TVA for processing.

During lignin production approximately 20 batch runs of MSW hydrolysis were processed to produce lignin material for co-fire testing. The lignin residue from the filter press was loaded into drums. Approximately 1000 lb of lignin were produced to meet the co-fire testing requirements.

3.4 Lignin Dewatering Testing

Lignin washing and dewatering occurred at TVA, providing washed feed for co-fire testing at EERC. Seven drums of lignin material were washed and dewatered. After drumming of the lignin material, the bio-fuel was shipped to EERC along with the bio-solids for Task 7 of this project, the combustion testing of the bio-fuels.

3.5 Combustion Testing

EERC will be performing the combustion testing. This testing will evaluate the fuel properties and potential impacts of co-firing lignin fuel with coal in the TVA-Colbert facility. The lignin and bio-solids material has been shipped to and received by EERC. TVA-Colbert has provided approximately 5000 lb of the standard TVA-Colbert coal for EERC to use as a baseline material for the combustion testing. EERC has received and pulverized the coal to a standard combustion grind (i.e., 70% to 80% of the coal particles <75 µm). Proximate and ultimate analyses of the as-received fuels have also been completed. Major, minor, and trace element analyses of the fuels are in progress.

The testing tentatively scheduled for this past quarter was delayed due to high winds at the EERC facility and planned repairs and modifications to the test boiler system. Currently, co-fire testing is scheduled to begin on Thursday, October 23, with a combustion test of the baseline coal. Testing of fuel blends including mixtures of coal, lignin, and bio-solids are scheduled to continue until early December.

3.6 Preliminary Engineering Interface Assessment and Design for TVA Coal-Fired Facility

The Colbert fossil plant consists of five pulverized coal-fired electricity generating units. Units 1 through 4 are identical and have the following characteristics:

- Capacity 200 MW
- Main steam flow 1,287,000 lb/hr
- Main steam pressure 1815 psig
- Main steam temperature 1050°F
- Reheat steam flow 1,122,000 lb/hr
- Reheat steam pressure 402 psig
- Reheat steam temperature 1050°F
- Steam turbine extractions eight at various pressures

Units 1 through 4 began commercial operation in 1955. Unit 5 is a unique, larger capacity (500 MW) unit and was not considered as a steam supply source.

HGI provided TVA with the design case steam requirements of the Masada facility. The requirements include the following:

- Steam pressure 150 psig
- Steam quality saturated
- Base demand 217,420 lb/hr
- Peak demand 229,420 lb/hr

The peak demand is the basis for the TVA engineering assessment. Of the steam exported to the waste processing facility, 82% would be returned to the Colbert plant as condensate.

The design of the steam supply system is complete. For reliability reasons, the steam supply arrangement would be configured so that steam would be supplied from one unit or equally divided from two units. Main steam from the steam generators would be the source. The steam conditions required by the waste processing facility would be met by attemperation and throttling. Steam export would reduce electrical generation from the plant and increase plant heat rate. Analysis of these impacts on the turbine cycle has been completed.

The steam pipe routing has been finalized and the environmental review completed. The selected route had no significant environmental impacts. The selected pipeline route includes 7,345 ft of pipeline with four road crossings and one crossing of Cane Creek.

A preliminary steam price has been determined based upon the cost estimate for the steam supply system, the output and heat rate impacts resulting from the potential steam export, and steam supply system maintenance costs.

4. **CONCLUSION**

The design criteria of the MSW to ethanol facility for this study have been completed. The delay of suitable feed material delayed the lignin production operations; however, a suitable MSW feed material was delivered and feed conditioning was completed. Hydrolysis operations and lignin production in the TVA facility were completed. Lignin washing and dewatering were completed. Lignin fuel and bio-solids were shipped to the EERC testing facility for co-fire evaluation. A baseline coal from TVA-Colbert was supplied to EERC and co-fire testing is scheduled to be completed during the upcoming quarter. Preliminary coal processing was completed to facilitate combustion testing.

The TVA-Colbert fossil plant is fully capable of providing a reliable steam supply for the proposed Masada waste processing facility. The steam supply connection point in the Colbert plant steam cycle has been identified. The pipeline routing from the Colbert powerhouse to the Colbert plant boundary has been identified. The environmental review of the pipeline routing has been completed and no impacts have been identified. The cost estimate for steam supply system is underway and this task in the project is nearing completion.

5. LIST OF ACRONYMS AND ABBREVIATIONS

DOE	Department of Energy
EERC	Environmental Energy Research Center
HGI	Harris Group Inc.
MRG	Masada Resource Group, LLC
MSW	Municipal Solid Waste
NETL	National Energy Technology Laboratory (also FETC, Federal Energy Technology Center)
PFD	Process Flow Diagram
RDF	Refuse Derived Fuel (also MSW)
SS	Sewage Sludge
TVA	Tennessee Valley Authority
TVA-PPI	TVA Public Power Institute
WWT	Waste Water Treatment