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High-Solids Black Liquor Firing in Pulp and Paper Industry Kraft Recovery Boilers

Quarterly Report Phase 1a: Black Liquor Gasifier Evaluation

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MASTER

PREPARED BY:
Babcock & Wilcox
Research and Development Division
1562 Beeson Street
Alliance, Ohio 44601
(216) 821-9110

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Background and Summary

This project phase addresses the following workscope:

- Conduct bench-scale tests of a low temperature, partial combustion gasifier.
- Prepare a gasifier pilot-plant preliminary design and cost estimate and prepare a budgetary cost estimate of the balance of the program.
- Outline a test program to evaluate gasification.
- Prepare an economic / market analysis of gasification and solicit pulp and paper industry support for subsequent phases.
- Prepare a final report and conduct a project review prior to commencement of work leading to construction of any pilot scale components or facilities.

This report describes work completed on this project in the calendar quarter beginning in April and ending in June, 1996. The primary accomplishments included completion of installation of the bench-scale black liquor gasifier and supporting systems, preparing test plans and related safety procedures and detailed operating procedures, defining the functional design requirements and outlining the test plans for the pilot-scale gasifier, and preparing a preliminary economic assessment of the black liquor gasifier. This work accomplished under Phase Ia during this period is further described by task in the sections that follow.

Task 1 - Bench-Scale Facility Construction, and Testing

Bench-Scale Facility Fabrication. The test apparatus fabrication, aside from some minor insulating and instrument work, was completed. The major activities involved in this process included:

- Completing the gasifier drain containers (bed solids drain and cyclone drain).
- Installing the gasifier vessel and installation of support and gas abatement equipment.

The test apparatus and all support and gas abatement systems are described in Attachment 1. This description includes a simplified process equipment diagram, and photographs of the overall system and individual components.

Procurement of Key Consumable Material

- We identified a supplier to pelletize the dried black liquor solids. That supplier successfully pelletized a sample of material in their lab. We successfully ground the trial pellets to the target size and evaluated swelling characteristics in our laboratory. We forwarded approximately 1000 pounds of powder to the supplier for production of the final material. However, on July 2, the supplier notified us that they had determined that pelletizing in their production equipment was not possible and they withdrew from the project. The approach for July is to salvage sufficient material for up to two test runs, and attempt alternate means to pelletize or briquette the material. If our approaches to properly size the material for solids

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feeding fail, the backup plan is to supply liquid black liquor at sufficiently low solids to pump in our test facility and adjust test conditions accordingly. Changing to liquid feed from solids feed will utilize the same over-the-bed liquor supply point, but naturally will use a different feed system.

Test Preparation and Equipment Checkout

Test preparation and equipment checkout activities included:

- Developing gas chromatography methods for analysis of the product gas. These methods were documented and calibration runs were completed using the gas standards acquired previously.
- Completing the test plans including the identification of target test conditions and preparation of test data sheets.
- Revising the job safe practice and detailed test operating procedures document as needed.
- Calibrating test instruments.
- Connecting power to the electric heaters and tested the heaters at limited power.
- Completing preliminary tests of the air, nitrogen, and steam supply systems.
- Connecting and testing the toxic gas monitoring system.

Task 2 - Pilot Plant Design and Cost Estimate

We developed the pilot-scale process flow diagram, and preliminary functional specification for the major components of the system and reviewed these internally. We revised these items to incorporate the changes identified by that review. We updated the preliminary heat and material balance for the pilot-scale unit. We completed a preliminary evaluation of materials of construction for the major components and piping for the pilot-scale unit. These four items: the process flow diagram, heat and material balance, functional specification, and materials of construction recommendations, will provide the basis for requests for budgetary cost bids by potential suppliers of major components for the pilot-scale unit.

Task 3 - Pilot Plant Test Program Outline

We completed a draft pilot plant test program outline. This outline may be revised depending upon specific results of the bench-scale test program.

Task 4 - Economic Market Analysis and Industry Support for Follow-on Phases

We completed a preliminary economic evaluation of a 480,000 lbs. black liquor (dry solids) per day gasifier design. The evaluation included comparisons with a conventional recovery boiler technology, a stand alone gasifier with the product gas being utilized by the mill in place of purchased

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fuel, and a novel combined cycle approach. The evaluation considered three cost scenarios, high, mean, and low. The major costs affecting these scenarios are the capital costs and the fuel costs. Fuel costs were taken as high cost being that for natural gas, mean cost being that for a weighted average of natural gas, oil, and coal, and low cost being that for coal. Capital costs were varied in conjunction with the fuel costs with the high, mean, and low costs reflecting the range of estimated capital costs for the cases evaluated.

The analysis methods used are simplified and are limited to providing results that should only be used to compare the cases examined in the study using the same relative investment evaluation techniques and consistent assumptions. Future work might consider greater depth to the analysis; however, this first level of analysis provides sufficient results to make the following interpretations. The major conclusions are:

- Fuel prices have a major impact on the results. In-general, conventional recovery technology and a black liquor gasifier that generates a fuel gas to displace purchased fuel are favored for the higher cost scenarios since the commodity being displaced, purchased fuel, has a higher value under these scenarios. The combined cycle is favored for the lower cost scenarios.
- The gasifier displacing purchased fuel is superior or comparable to conventional recovery technology and offers greater potential flexibility for use of the end product, i.e. a low heating value fuel gas versus steam. This indicates that black liquor gasification technology continues to be worth pursuing.
- The combined cycle is superior to conventional technologies under the low cost scenario, and depending upon the specific cycle assumptions, may be comparable to the conventional technologies under the mean cost scenario. Since there has been limited investment in evaluating the combined cycle portion of this technology to date, this indicates that additional investigation of more specific cycles and equipment options is worth pursuing.

Task 5 - Project Phase I Final Report and Project Management

Monthly reports were submitted, and internal issues related to test planning, code compliance, and test safety were resolved.

An internal review of the approach for pilot-scale testing and the pilot-scale functional and equipment requirements was completed.

Approvals:

Project Leader W T Southards
W. T. Southards

R&DD Manager D R Rowley
D. R. Rowley

Attachment 1 - Description of the Bench-Scale Black Liquor Gasifier

A simplified schematic of the bench-scale black liquor gasifier is shown in Figure 1. The key test item is the fluidized bed gasifier reactor (located on the left of the figure) in which gasification occurs. The balance of the equipment:

- Supplies the reactants; black liquor solids, and heated air, nitrogen, and steam; to the gasifier,
- Removes gas, solids, or heat from the gasifier, or
- Cools the gas downstream of the gasifier, and removes condensing tar and water.

Within the gasifier reactor, heated air, nitrogen, and steam fluidize a bed of solids and react with the black liquor solids supplied. The bed solids will initially be an inert material (silica sand) that will be displaced by the reacting black liquor solids and the resulting product solids, primarily sodium carbonate. The black liquor solids react with the steam and air mixture to produce a fuel gas containing hydrogen, carbon monoxide, and methane. The sulfur reacts primarily to form hydrogen sulfide, but may also form other reduced sulfur gas species. Spent bed material is drained from the fluidized bed to a drain container that can be isolated and removed from the system.

The black liquor solids are supplied from a screw feeder via the supply tube into the reactor. The fluidizing air/nitrogen and steam is metered to the system and preheated with a two stage electric heater. The supply temperature range is 900F to 1200F.

Product gas leaving the bed is cooled to approximately 500F in the free board region of the gasifier by an air cooling jacket. A cyclone removes particulate material to a drain container that can be isolated and removed from the system. The gas is then further cooled in boiling water heat exchanger (BWHX) to approximately 200F to 300F and tars that are condensed are collected in a tar trap at the bottom of the BWHX. Samples of the gas for analysis by gas chromatography are taken immediately downstream of the tar trap. The gas is further cooled to approximately 100F in the condenser and water condensed during this cooling step is collected in the water trap. The gas is then thermally oxidized for disposal in a existing fluidized bed combustor.

Pictures of the equipment prior to installing the insulation are shown in Figures 2 to 4. Specific components are identified in these figures. The gasifier system is contained in a curtained enclosure that is vented via the laboratory fume hood system for safety reasons. The enclosure is to mitigate dispersion of the product gas in the event of a leak. A monitoring system to detect any system leaks is also in place within the enclosure.

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Figure 1 - Schematic of the Bench-Scale Black Liquor Gasifier.

Figure 2 - Bench-Scale Black Liquor Gasifier Prior to Insulating.

Figure 3 - Bench-Scale Black Liquor Gasifier and Feed System Components.

Figure 4 - Bench-Scale Black Liquor Gasifier - BWHX, Tar Trap, Water Condenser, and Water Trap.