



**GREENHOUSE GAS EMISSIONS CONTROL BY OXYGEN FIRING IN  
CIRCULATING FLUID BED BOILERS  
(Phase II – Evaluation of the Oxyfuel CFB Concept)**

**SEMI ANNUAL TECHNICAL PROGRESS REPORT**

**Reporting Period Start and End Date: May 15 – September 26, 2003**

**Key ALSTOM Power Inc. Personnel**

**John L. Marion, Project Manager  
Nsakala ya Nsakala, Project Leader**

**Report Issue Date: November 9, 2003**

**DOE Award No.: DE-FC26-01NT41146**

**Prepared by**

**US Power Plant Laboratories  
ALSTOM Power, Inc.  
2000 Day Hill Road  
Windsor, Connecticut 06095**

**Prepared for**

**U.S. Department of Energy  
NETL ADD Document Control Bldg. 921  
National Energy Technology Laboratory  
P.O. Box 10940  
Pittsburgh, Pennsylvania 15236-0940**

## **DISCLAIMER**

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

## **ABSTRACT**

The overall project goal is to determine if carbon dioxide can be captured and sequestered at a cost of about \$10/ton of carbon avoided, using a newly constructed Circulating Fluidized Bed combustor while burning coal with a mixture of oxygen and recycled flue gas, instead of air.

This project is structured in two Phases. Phase I was performed between September 28, 2001 and May 15, 2002. Results from Phase I were documented in a Topical Report issued on May 15, 2003 (Nsakala, et al., 2003), with the recommendation to evaluate, during Phase II, the Oxyfuel-fired CFB concept. DOE NETL accepted this recommendation, and, hence approved the project continuation into Phase II. Phase 2. The second phase of the project – which includes pilot-scale tests of an oxygen-fired circulating fluidized bed test facility with performance and economic analyses – is currently underway at ALSTOM's Power Plant Laboratories, located in Windsor, CT (US). The objective of the pilot-scale testing is to generate detailed technical data needed to establish advanced CFB design requirements and performance when firing coals and delayed petroleum coke in oxygen/carbon dioxide mixtures.

Results will be used in the design of oxygen-fired CFB boilers – both retrofit and new Greenfield – as well as to provide a generic performance database for other researchers. At the conclusion of Phase 2, revised costs and performance will be estimated for both retrofit and new Greenfield design concepts with CO<sub>2</sub> capture, purification, compression, and liquefaction.

## Table of Contents

<b>PROJECT DESCRIPTION .....</b>	<b>1</b>
<b>Overall Project Objective And Work Breakdown Structure.....</b>	<b>1</b>
<b>EXPERIMENTAL.....</b>	<b>1</b>
<b>Phase II Specific Objectives .....</b>	<b>2</b>
<b>RESULTS AND DISCUSSION .....</b>	<b>2</b>
<b>Phase II Related Activities .....</b>	<b>2</b>
<b>Work Planned for Next Reporting Period .....</b>	<b>3</b>
<b>BUDGET STATUS .....</b>	<b>3</b>
<b>CONCLUSIONS .....</b>	<b>3</b>
<b>REFERENCES .....</b>	<b>4</b>

## List of Figures

Figure 1: Project's Work Breakdown Structure (WBS) .....	1
Figure 2: Budget Profile.....	3

## PROJECT DESCRIPTION

### Overall Project Objective And Work Breakdown Structure

The overall project goal is to determine if carbon dioxide can be recovered at an avoided cost of \$10/ton (or less) of carbon avoided, using a newly constructed Circulating Fluidized Bed combustor while burning coal with a mixture of oxygen and recycled flue gas, instead of air.

The work breakdown structure (WBS) of this project is presented in Figure 1. Phase I (Tasks 1-3) was performed between September 28, 2001 and May 15, 2002. Results from Phase I were documented in a Topical Report issued on May 15, 2003, with the recommendation to evaluate, during Phase II, the Oxyfuel-fired CFB concept. DOE NETL accepted this recommendation, and, hence approved the project continuation into Phase II, as described below.

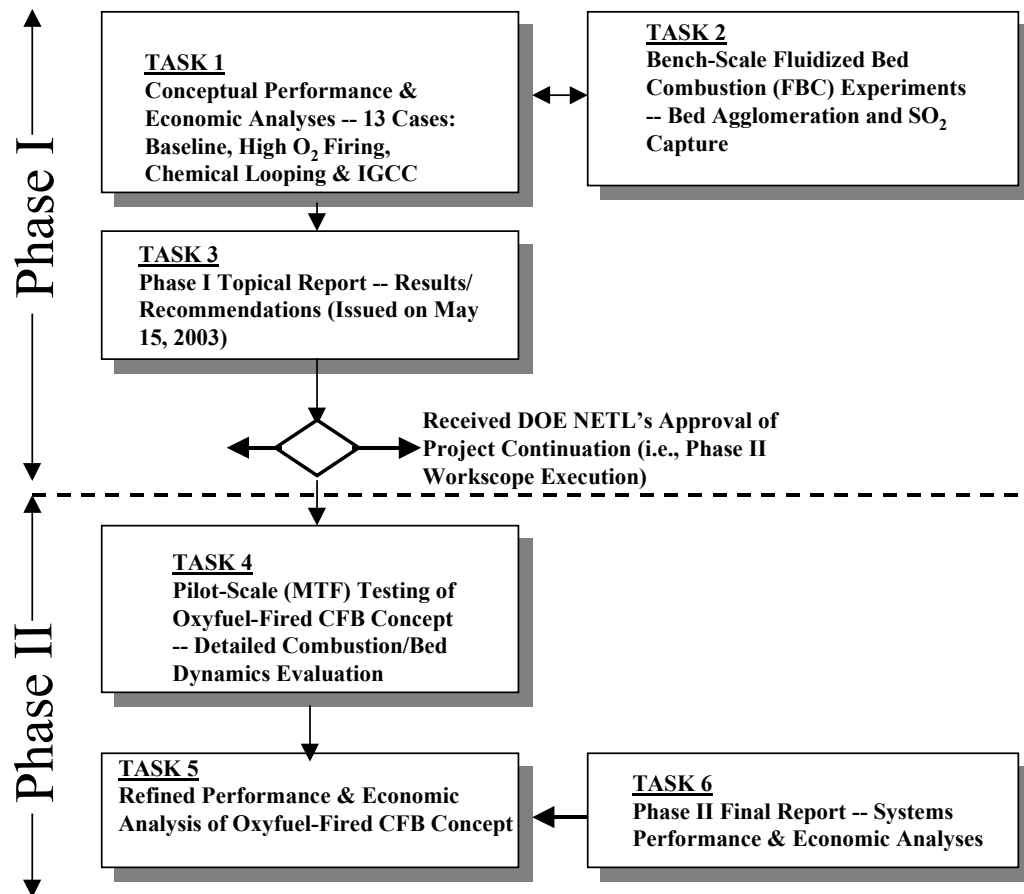


Figure 1: Project's Work Breakdown Structure (WBS)

## EXPERIMENTAL

Phase II, which is in effect from May 15, 2003 to October 27, 2004, consists of pilot-scale testing of the oxyfuel-fired circulating fluidized bed technology (CFB) concept, updating the performance and economic analysis results obtained from this concept in Phase I, and documenting the results in a final report (Tasks 4-6, Figure 1).

## **Phase II Specific Objectives**

The specific objective of the Phase II workscope is to generate a refined technical and economic evaluation of the Oxyfuel-fired CFB concept, with the benefits from pilot-scale testing of the same concept. Phase II workscope has been developed based upon the findings from Phase I and will specifically address both retrofit (moderate O<sub>2</sub> enrichment/ high flue gas recirculation) and Greenfield applications (high oxygen enrichment/low flue gas recirculation). The objective of the pilot-scale testing is to generate detailed technical data needed to establish advanced CFB design requirements and performance when firing coals and delayed petroleum coke in O<sub>2</sub>/CO<sub>2</sub> mixtures. Firing rates in the pilot test will range from 2.6 to 9.6 MMBtu/hr (0.8-2.8 MWth). Pilot-scale testing will be performed at ALSTOM's Multi-use Test Facility (MTF), located in Windsor, Connecticut. Outputs from this testing will address key technical parameters including:

- Flue Gas Quality
- Bed Dynamics
- Heat Transfer to the Waterwalls
- Flue Gas Desulfurization
- NO<sub>x</sub> Emissions Reduction
- Other Pollutants' Emissions (N<sub>2</sub>O and CO)
- Bed and Ash Characteristics (e.g., Potential Bed Agglomeration)

Results will be used in the design of oxygen-fired CFB boilers – both retrofit and new greenfield -- as well as provide a generic performance database for other researchers. At the conclusion of Phase II, revised costs and performance will be estimated for both retrofit and new greenfield design concepts with CO<sub>2</sub> capture, purification, compression, and liquefaction (See Phase I Topical Report of May 15, 2003 -- Cases 2a and 2).

## **RESULTS AND DISCUSSION**

### **Phase II Related Activities**

Task 4: Multi-use Test Facility (MTF) Testing. This facility will be modified to test fire two coals and one delayed petroleum coke in air and various O<sub>2</sub>/CO<sub>2</sub> mixtures containing potentially up to 70% O<sub>2</sub> by volume. Fuel firing rates will range from about 2.6 to 9.6 MMBtu/hr (0.8 - 2.8 MWth). To achieve this flexibility, while maintaining the superficial gas velocity at about 15 ft/sec (4.6 m/sec), the inner diameter of the MTF will be reduced from 40 to 21 inches (1016 - 553 mm). Progress:

- Reviewed the proposed test matrices and fuel and limestone sample acquisition strategies
- Made heat transfer calculations and generated the furnace modification specifications
- Started generating the drawings, pertinent to furnace modification
- Received from Praxair, Inc., the preliminary P&ID of the O<sub>2</sub> and CO<sub>2</sub> supply system. Currently, in the process of interacting with Praxair for the purpose of getting Praxair to issue a Quote for this supply system.
- Sample Acquisitions:
  - Contacted Plasma, Inc. of Butte, Montana, about helping ALSTOM obtain a tonnage quantity of a delayed petcoke sample from Mobil Torrance Refinery, which is connected to the Bakersfield EOR (enhanced oil recovery) project. Plasma, Inc. is ready to make arrangements for the shipment of one truckload of the petcoke.
  - Started the process of acquisition of the coal and limestone samples used at the "Base Case" CFB plant. The acquisition of the second coal, from the Illinois #6 seam, has not yet been implemented, because a request was made in writing on 10/15/03 by the PI (Dr. Nsakala ya Nsakala) to the COR (Dr. Karen Cohen) to substitute it with Pittsburgh #8 coal (the reason for this fuel switching was specified in the request).
- Planned MTF Testing schedule:
  - Campaign #1 (With the coal sample from the CFB plant used as "Base Case" in Phase I): January 2004

- Campaign #2 (With the Illinois #6 coal or Pittsburgh #8 coal, plus a petcoke sample): February 2004.

Task 5: Refined Performance & Economic Analysis of the Oxyfuel Fired CFB Concept: No activity

Task 6: Project Management & Reporting: Issued informal technical progress reports and required quarterly financial status report; interacted with the personnel from the DOE, ALSTOM, Praxair, and other vendors on various issues concerning the project execution.

#### Work Planned for Next Reporting Period

- *MTF Modification:* Complete detailed furnace design work geared toward its modification for oxy-fuel firing; Order long lead items.
- *O<sub>2</sub> and CO<sub>2</sub> Supply Infrastructure:* Complete the activity associated with Praxair's Quote on O<sub>2</sub> and CO<sub>2</sub> supply vis-a-vis its scope and cost, and delivery.
- *Sample Acquisitions:* Order all the three test fuels, plus a limestone sample (from the "Base Case" CFB plant).

#### BUDGET STATUS

Figure 2 depicts various budget scenarios (Total budget, total budget released, inception-to-date expenditures, remaining budget, etc.). The overall expenditures are behind the projected expenditures, due to late start of the MTF design specs. For MTF modification. To keep to the testing schedule given above, an additional 600 kUSD needs to be released for the period extending from November 1, 2003 to March 31, 2004. This request for fund release was made in writing on October 14, 2003.

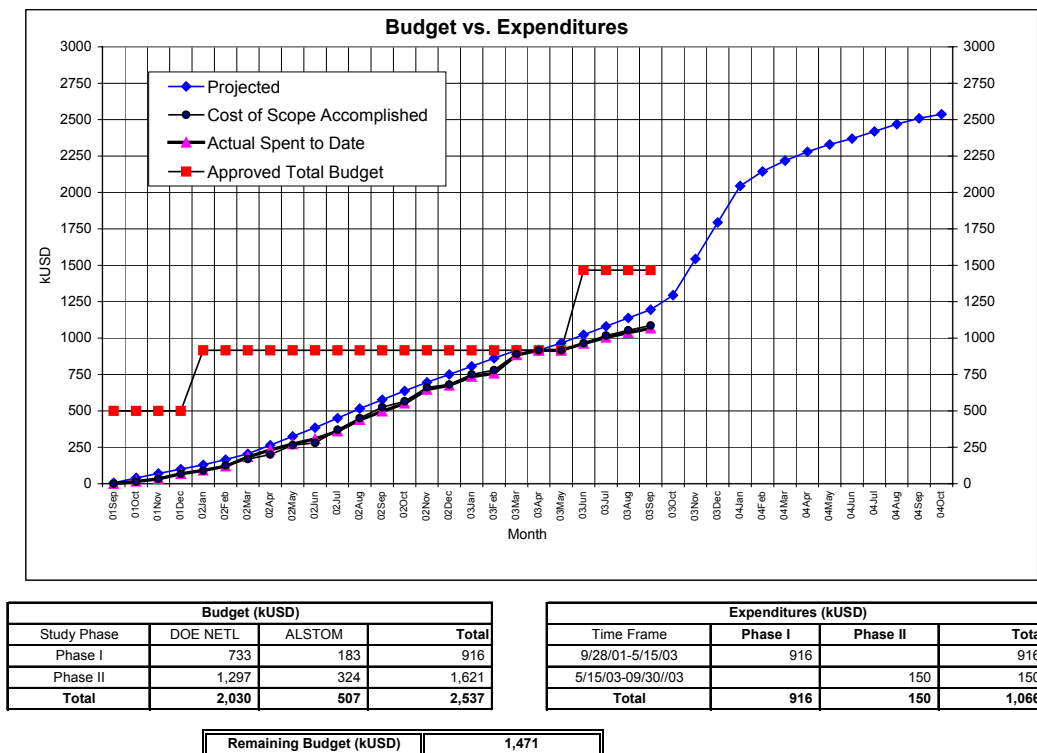


Figure 2: Budget Profile

## **CONCLUSIONS**

The late start of the MTF modification is not anticipated to affect the overall project performance schedule, provided that 600 kUSD is released to cover the period extending from November 1, 2003 to March 31, 2004.

## **REFERENCES**

Marion, J., Bozzuto, C., Nsakala, N., Liljedahl, G., Andrus, H., and Chamberland, R., "Greenhouse Gas Emissions Control by Oxygen Firing in Circulating Fluidized Bed Boilers: Phase I – A Preliminary systems Evaluation." Topical Report, Prepared under DOE NETL Contract DE-FC26-01-NT41146, May 15, 2003