DENSE MEDIA CYCLONE OPTIMIZATION

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Precision Testing Laboratories

July-September 2001 Quarterly Report

Heavy Media Cyclone Optimization - Virginia Tech

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ABSTRACT

All work associated with Task 1 (Baseline Assessment) was successfully completed and preliminary corrections/recommendations were provided back to the management at each test site. Detailed float-sink tests were completed for Site #1 and are currently underway for Sites #2-#4. Unfortunately, the work associated with sample analyses (Task 4 – Sample Analysis) has been delayed because of a backlog of coal samples at the commercial laboratory participating in this project. As a result, a no-cost project time extension may be necessary in order to complete the project. A decision will be made at the end of the next reporting period. Some of the work completed this quarter included (i) development of mass balance routines for data analysis, (ii) formulation of an expert system rule base, (iii) completion of statistical computations and mathematical curve fits for the density tracer test data. In addition, an “O&M Checklist” was prepared to provide plant operators with simple operating and maintenance guidelines that must be followed to obtain good HMC performance.

Dense Medium Cyclone Optimization (Proposal #60)

- **Principal Investigator:** Gerald Luttrell (Virginia Tech)
- **NETL Project Manager:** David M. Hyman
- **Partners:** Massey Coal Services
Partition Enterprises (Australia)
Precision Testing Laboratory
- **Total Project Cost:** \$320K
 - DOE Share: \$154K
 - Participant Share: \$166K
- **Project Period:** 12 months
- **Project Start Date:** 14 Dec. 2000

Background

- **Heavy Media Cyclones (HMCs)**
 - Serves as the “workhorse” in the coal industry for removing waste rock from valuable coal
 - In the U.S., HMCs represent an installed capacity of >85,000 ton/hr
 - Problem - Improper operation can result in large losses of recoverable coal to the waste product
 - losses estimated to be more than \$45 million annually

Background

Principle of Operation

Rotating suspension of media forces lighter particles to the center and upward through the vortex finder, while heavier particles spiral outward and down through the apex.

Background

Background

- **Given adequate operating pressure and low wear, the two common causes of major yield loss for HMCs are:**
 - floats overload
 - surging
- **Both conditions lead to:**
 - lowering of the SG cutpoint
 - misplacement of relatively low density material to reject (i.e., a reduction in clean product yield)

Background

- Malfunctions or design flaws that give different cutpoints for a multi-unit HMC circuit adversely impacts performance.
- This problem is very severe when low-ash coals are produced.
- Problems may include poor feed distribution, media contamination, overloaded circuits, worn apexes, etc.

Project Objectives

- To develop a set of three basic engineering tools to improve the efficiency of heavy medium cyclone (HMC) circuits:
 - low cost tracers to rapidly assess HMC performance
 - mathematical process models to predict the influence of changes in operating and design variables on HMC performance
 - model-based expert system to provide operators with a user-friendly interface for evaluating, optimizing, and troubleshooting HMC circuits

← Management

← Engineers

← Operators

Photo Library

Shane Bomar (graduate student) and Chris Wood (Partition Enterprises) preparing for plant sampling and density tracer testing.

Density tracers (32 mm cubes) sorted into groups of 20 each (1.32 to 2.50 SG) just prior to being introduced into the cyclone feed stream.

Photo Library

A bank of parallel coarse coal heavy media cyclones that were sampled in detail and evaluated using the density tracers .

An installation of twin parallel coarse coal heavy media cyclones that were sampled in detail and evaluated using the density tracers .

Project Cost Summary

Source	First Year		Second Year		Third Year		Totals	
	Plan	Actual	Plan	Actual	Plan	Actual	Plan	Actual
Participant	\$166K	\$96*	0	---	0	---	\$166K	\$96*
DOE	\$154K	\$82	0	---	0	---	\$154K	\$84
Total	\$320K	\$180	0	---	0	---	\$320K	\$180

*Includes Encumbered Costs (Sample Analysis)

KEY:

Plan = Planned costs for the full year.

Actual = Actual costs through the reporting period.

Milestones and Status

Major Milestone	Description of Planned Activity
1 - Baseline Assessment	Initial inspection and testing to establish existing performance of DMC circuits at four selected plant sites.
2 - Circuit Modification	Modification of plant circuits and/or operating practices based on information from the Baseline Assessment.
3 - Follow-Up Assessment	Secondary inspection and testing to establish technical and economic benefits of recommended modifications.
4 - Sample Analysis	Detailed float-sink testing of representative samples from the DMC circuits at the four selected plant sites.
5 - Data Analysis/Simulation	Detailed analysis of density tracer and float-sink test data (including mass balancing and simulation studies).
6 - Expert System Development	Development of mathematical routines and expert rules that can be used by operators for DMC optimization.
7 - Concept Assessment	Technical and economic evaluations of the project work (including preparation of technical reports).

Milestones and Status

TASK DESCRIPTION	Duration (Month)											
	J	F	M	A	M	J	J	A	S	O	N	D
1. Baseline Assessment		Project Planning	Evaluate Site 1	Evaluate Site 2	Evaluate Site 3	Evaluate Site 4						
2. Circuit Modification								Modifications Sites 1-4				
3. Follow-Up Assessment									Re-evaluate Sites 1-4			
4. Sample Analysis						Analyze Site #1	Analyze Site #2	Analyze Site #3	Analyze Site #4		Analyze Sites 1-4	
5. Data Analysis/Simulation				Experimental Data Analysis/Mass Balancing				Model/Simulator Development				
6. Expert System Development				Formulation of ES Rules				Development of ES Software				
7. Concept Assessment			Q 1			Q 2			Q 3		Technical/Economic Evaluation & Final Report

Planned

Completed

Milestones and Status

Planned Milestone	Scheduled	Completed	Current Status
1 - Baseline Assessment	July '01	July '01	Completed All Baseline Tests (5 Plant Sites and 7 Circuits)
2 - Circuit Modification	Sept. '01	---	Provided Draft Recommendation Report (Detailed Report Pending)
3 - Follow-Up Assessment	Oct. '01	---	---
4 - Sample Analysis	Nov. '01	---	Completed Analysis for Site #1 (Site #2 Underway & Sites 3-4 Delayed)
5 - Data Analysis/ Simulation	Nov. '01	---	Completed Mass Balancing & Site 1 Data Analysis (Developing Simulation Routines)
6 - Expert System Development	Nov. '01	---	Formulating ES Rule Base (Operators Checklist Now Available)
7 - Concept Assessment	Dec. '01	---	---

Milestones and Status

- Key Decision Points

Decision Points	Scheduled Date	Go / No-Go Decision?
Can the density tracers be successfully recovered in quantities that permit a statistically significant result? (YES)	July '01	Yes
Are modifications to operating practices and/or equipment required in light of the Baseline Assessment? (YES)	July '01	Yes
Can the required modifications be successfully completed within the schedule, scope and budget of the project? (???)	Sept. '01	Yes
Do the mass balances indicate that the experimental data are reliable and suitable for engineering computations? (???)	Sept. '01	Yes
Is the proposed optimization approach involving tracers and system software technically and economically attractive?	Dec. '01	No

Key Accomplishments

- Density tracers prepared and examined for quality control purposes.

Photograph of 64, 32, 16 and 8 mm density tracers that available for the evaluation of industrial heavy media circuits.

Key Accomplishments

- Custom sampling tools purchased and/or fabricated for each of the selected plant sites.
- More than 20 different types of sampling devices required.

Examples of sampling tools that were purchased or fabricated for the collection of density tracers and samples of clean coal, refuse and circulating media.

Key Accomplishments

- Five different plants evaluated (although only four originally proposed).

Photograph of one of the five coal preparation plants where the field testing of heavy media cyclones was performed.

Key Accomplishments

- Seven cyclone circuits sampled (up to 14 personnel required at some sites).

Photograph showing the collection of a sample of circulating media from the underside of the clean coal sieve.

Photograph showing the collection of density tracers from the clean coal drain-and-rinse screens below a bank heavy media cyclones.

Flowsheet for one of the heavy media circuits evaluated in this project .

Key Accomplishments

- Detailed cyclone inspections completed at all but one plant during maintenance shifts.

Inside view of a ceramic-lined heavy media cyclone obtained during the preliminary site inspections (as viewed through the apex).

Inspection of the apex of a ceramic-lined heavy media cyclone (as viewed after the removal of the underflow discharge hood).

Key Accomplishments

- Density tracer tests and associated statistical computations completed for all seven circuits.

R D	Number of Tracers . . .										% to U/flow
	in Feed a	retrieved from...								Recov ered b+c d	
		Overflow					Underflow				
		unit 1	unit 2	unit 3	unit 4	Total b	unit 1	unit 2	Total c		
1.50	40	14	5	3	6	28	0	2	2	30	7
1.52	40	10	4	6	9	29	0	0	0	29	0
1.54	40	10	1	6	9	26	0	1	1	27	4
1.56	40	9	2	5	9	25	0	2	2	27	7
1.58	40	7	5	3	12	27	2	7	9	36	25
1.60	40	8	2	2	6	18	3	10	13	31	42
1.62	40	1	2	0	4	7	11	18	29	36	81
1.64	40	0	0	0	0	0	8	29	37	37	100
1.66	40	0	0	0	0	0	14	19	33	33	100
1.68	40	0	0	0	0	0	8	30	38	38	100
1.70	40	0	0	0	0	0	7	26	33	33	100

Note: Low SG tail may indicate misplacement of low-ash coal.

Key Accomplishments

- Mathematical data fits conducted for all seven circuits using the tracer data.

Partition Number (%)

Conclusions

Partition curves generally sharp, but misplacement may occur at lower SG values for some plants.

Specific Gravity

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Key Accomplishments

- Mathematical simulations conducted for all seven circuits using the tracer data.

Key Accomplishments

- **Density tracers detected that most circuits suffered from poor control of media cutpoint.**
 - Problems attributed to poor k-ray calibration and improper manual density measurements.
 - Important for plants that also have heavy media baths (poor control can significantly impact profitability).

Plant Circuit	K-Ray SG	Darcy SG	Tracer SG
A1	1.40	1.47	1.43
A2	1.38	1.45	1.39
B1	1.58	1.65	1.75
B2	1.33	1.40	1.37
C	1.55	1.62	1.65
D	1.59	1.66	1.48
E	1.60	1.67	1.60

Key Accomplishments

- **Other problems identified by tracers...**
 - Plant A: Performance good, but feed distribution problem observed; media readings incorrect.
 - Plant B: Evidence of recoverable coal misplaced to refuse due to overload.
 - Plant C: Recoverable coal misplaced to refuse at low SG cutpoints (overload or surging); media reading incorrect.
 - Plant D: Cyclones suffering from severe overload; media readings incorrect.
 - Plant E: Performance good, but cutpoint lower than expected (probably due to overload).

Key Accomplishments

- Baseline reports assessing HMC performance provided to all plant operators.
- Items evaluated:
 - Media Density
 - SG Cutpoint
 - Circuit Ep
 - Potential Coal Losses
 - Potential Rock Recovery
- Recommendations provided for each site.

Key Accomplishments

- Detailed float-sink tests completed for Site #1 and underway for Sites #2-#4.
 - Problem: Analyses delayed because of sample backlog at the commercial laboratory (no-cost project time extension may be requested).

————— Increasing Specific Gravity —————→

Key Accomplishments

Good News!

- The density tracers showed that HMC performance was generally good for all plants.
 - Internal inspections showed that cyclone components were well maintained and well matched.
 - Recent changes in operating practices probably helped to improve HMC performance.

Good News!

- An expert system “checklist” has been prepared for plant operators.
 - Provides simple guidelines that must be followed to obtain good HMC performance.
 - Rules have been provided for HMC operation (e.g., cyclone pressure, media-to-coal ratio, overflow media split, media size and quality, K-ray calibration, cutpoint selection, etc.).
 - Rules for HMC maintenance have also been provided.

Good News!

- **Example - Required Media Split**

- ▶ – Rule: A minimum of 2/3 of the volume flow of media fed to the cyclone should report to overflow.
- ▶ – Method: Measure SG of feed, overflow and (through clean coal sieve), and underflow (through refuse sieve) and calculate split using:

$$\frac{SG_{\text{underflow}} - SG_{\text{feed}}}{SG_{\text{underflow}} - SG_{\text{overflow}}} > \frac{2}{3}$$

- ▶ – Sample Calculation: If feed=1.5, O/F=1.4, U/F=1.7, then OK since $(1.7-1.5)/(1.7-1.4) = 2/3$.
- ▶ – Correction: If calculated split < 2/3, use smaller apex to shift more media to overflow.

Project Recognition

- **International Conferences**

- “Optimization of Heavy Media Cyclone Circuits,” Accepted for publication and presentation, 2002 Meeting of the Society for Mining, Exploration and Metallurgy (SME), February 25-27, 2002, Salt Lake City, Utah.
- “Optimization of Heavy Media Cyclone Circuits,” Submitted for publication and presentation at the 19th International Coal Preparation Conference and Exhibition (Coal Prep 2002), April 30-May 2, 2002, Lexington, KY.

- **Short Courses and Workshops**

- Operating and Maintenance Standards for Heavy Media Cyclones,” Half-Day Workshop, Sponsored by Massey Coal Services, Chapmanville, WV, July 6, 2001 and August 17, 2001.

Commercialization Outlook

- **Commercialization ensured by project participants:**
 - Tracers blocks and tracer testing services will be made available to industry by Precision Testing (Beckley, WV) as a cooperative effort with Partition Enterprises (Australia).
 - Technical “know-how” will be distributed throughout the industry via written publications and oral presentations by Virginia Tech personnel.
 - Website is currently being prepared that will provide expert system software and simulation routines to interested parties at no cost.

Project Assessment

(Internal DOE Use Only)

- **Open Issues and/or Problems**
 - Sample analysis delays may require no-cost time extension.
 - Spending to date within budget limits.
- **Overall Assessment**
 - Off to a good start and work elements progressing well.
 - Findings of significant technical and economic importance.