U.S Department of Energy
Mining Industry of the Future

Round IV Projects

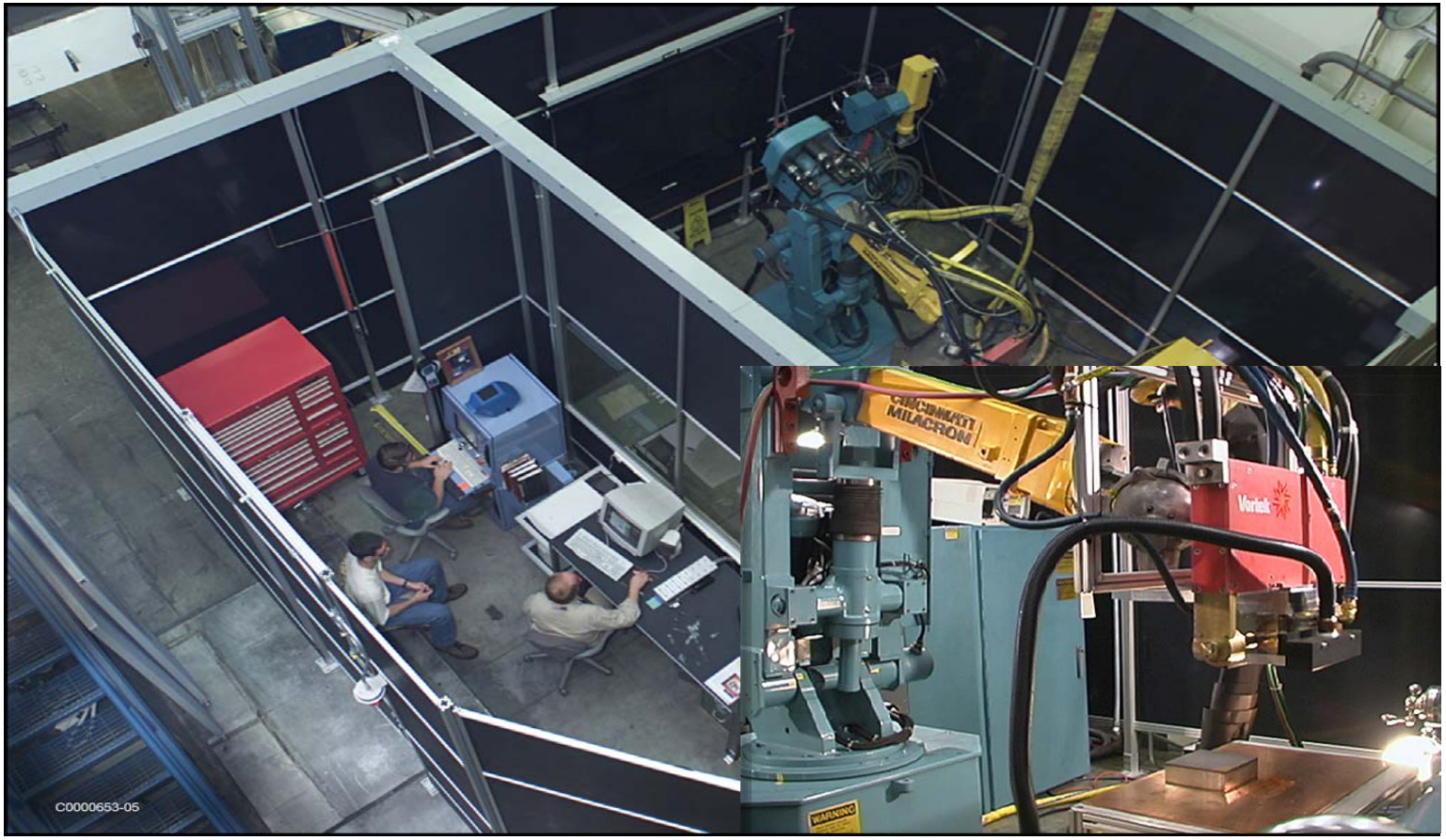
Advanced Surface Enhancement Technology for Decreasing Wear and Corrosion

- **Principal Investigator:** Daniel Tao
- **NETL Project Manager:** Morgan Mosser
- **Partners:** ORNL, Carbontronics Fuel Management, LLC., CONSOL, James River Service. Co., AMVEST Mineral Service, Inc., Florida Rock Industries, Inc., Kurtz Bros., Inc., Innovation Screen Technology, Jeffery Chain Corp., Energy Industries of Ohio, Kentucky Coal Association, Ohio Coal Development Office, Phelps Dodge Mining Company
- **Total Project Cost:** **$2,511,329**
  - DOE Share: $750,286
  - ORNL: $500,385
  - Participant Share: $1,260,658
- **Project Period:** **36 months**
- **Project Start Date:** **July 21, 2003**

Project Objectives

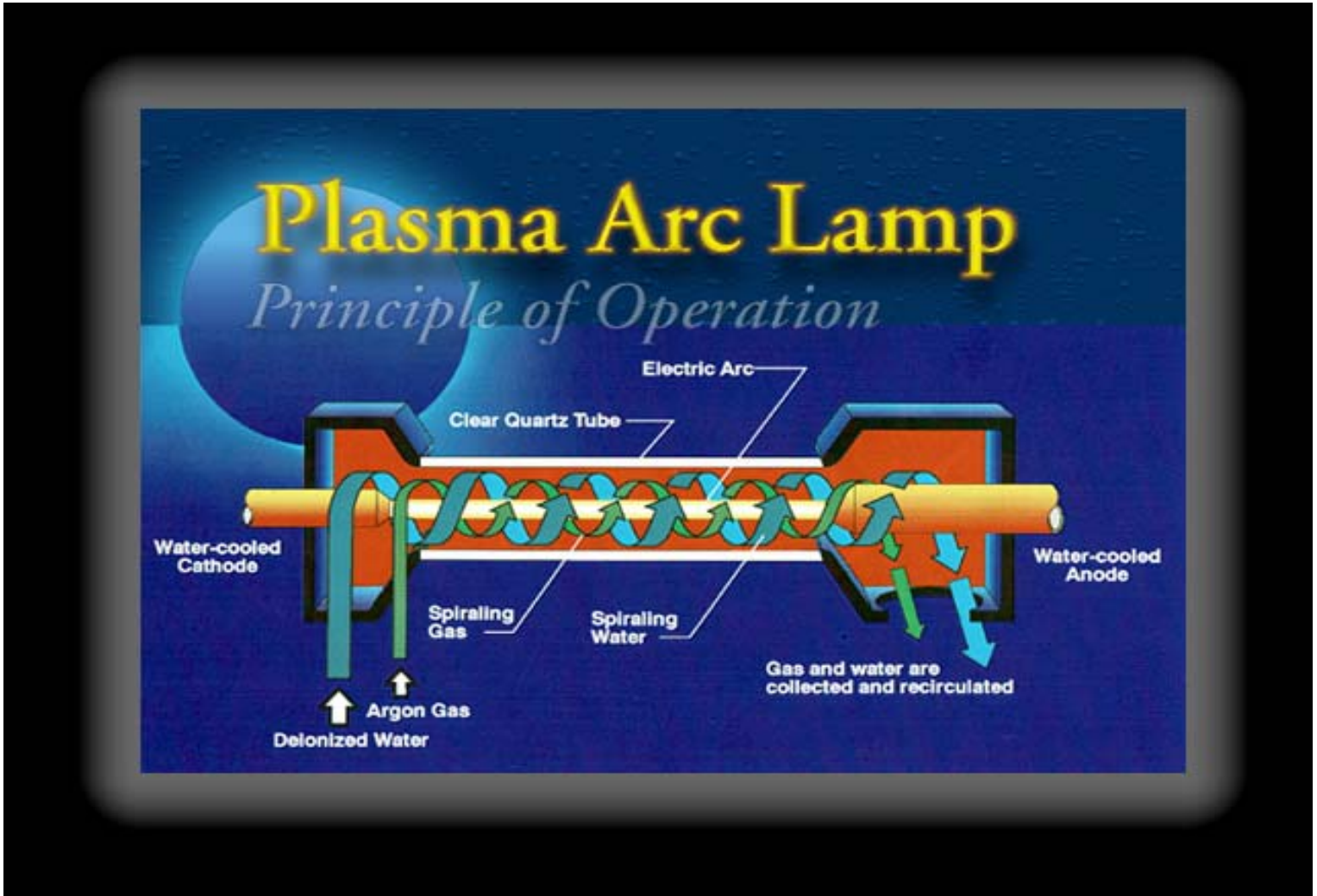
- **The overall objective the proposed program is to develop a cost-effective advanced surface enhancement technology for decreasing wear and corrosion rate by an order of magnitude of equipment that are widely used in mineral processing and coal preparation plants. Specific objectives include:**
  - Determine the surface enhancement method and its application conditions for screens, chain components for conveyors, and heavy medium vessel plates .
  - Evaluate wear and corrosion resistance of coated screens, chain components, heavy medium vessel plates and pug mill paddles with different coal and aggregate samples.
  - Investigate the dependence of wear and corrosion resistance as a function of surface enhancement method variables.
  - Conduct on-site evaluation of surface enhanced specimens at processing plants.
  - Perform economical analysis of the surface enhancement technology developed in this project.

Photo Library

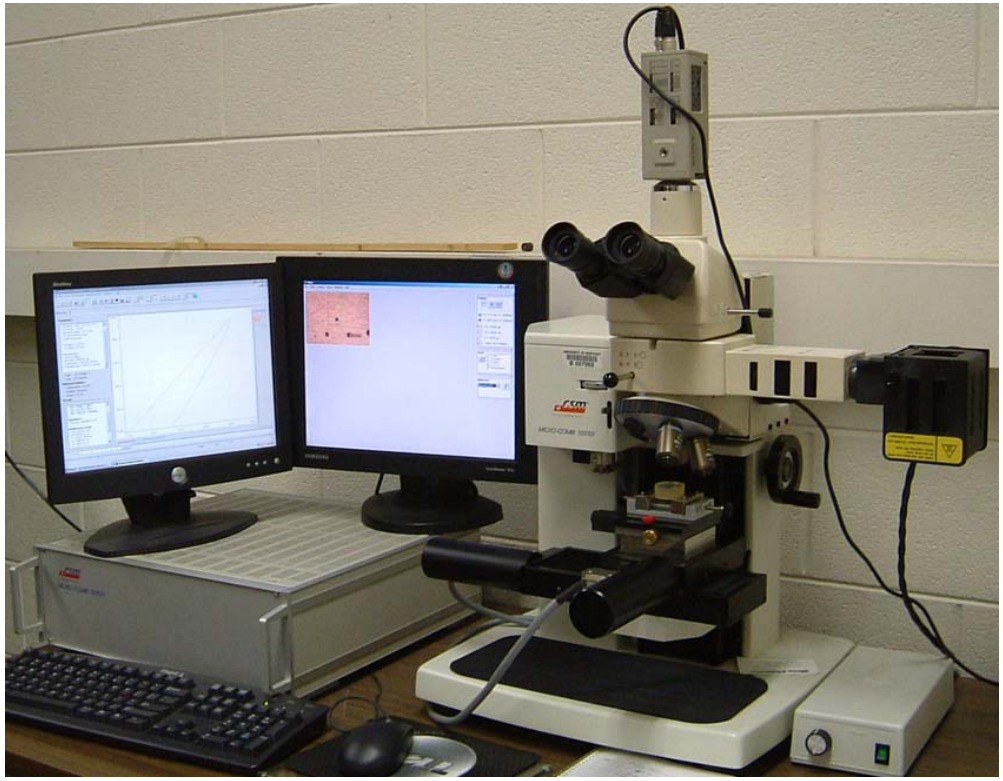


ORNL HDI Facility

High Density Infrared (HDI) Technology



CSM Combi Tester for Microhardness Testing (MHT) and Microscratch testing (MST)



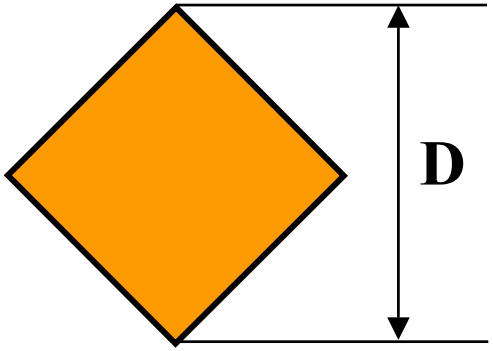
- Applied load value plotted against indenter position.

•Load/displacement curves provide data on mechanical characteristics.

•Quantitative hardness calculated by established models.

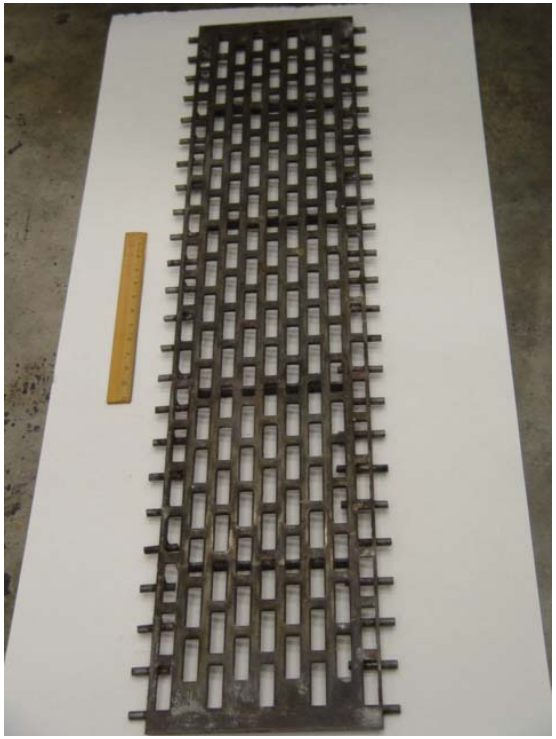
Micro-Hardness/Indentation Tester

Microindent:



Vickers Hardness (HV) = $1.8544 \times F/D^2$

Screen specimen from Massey

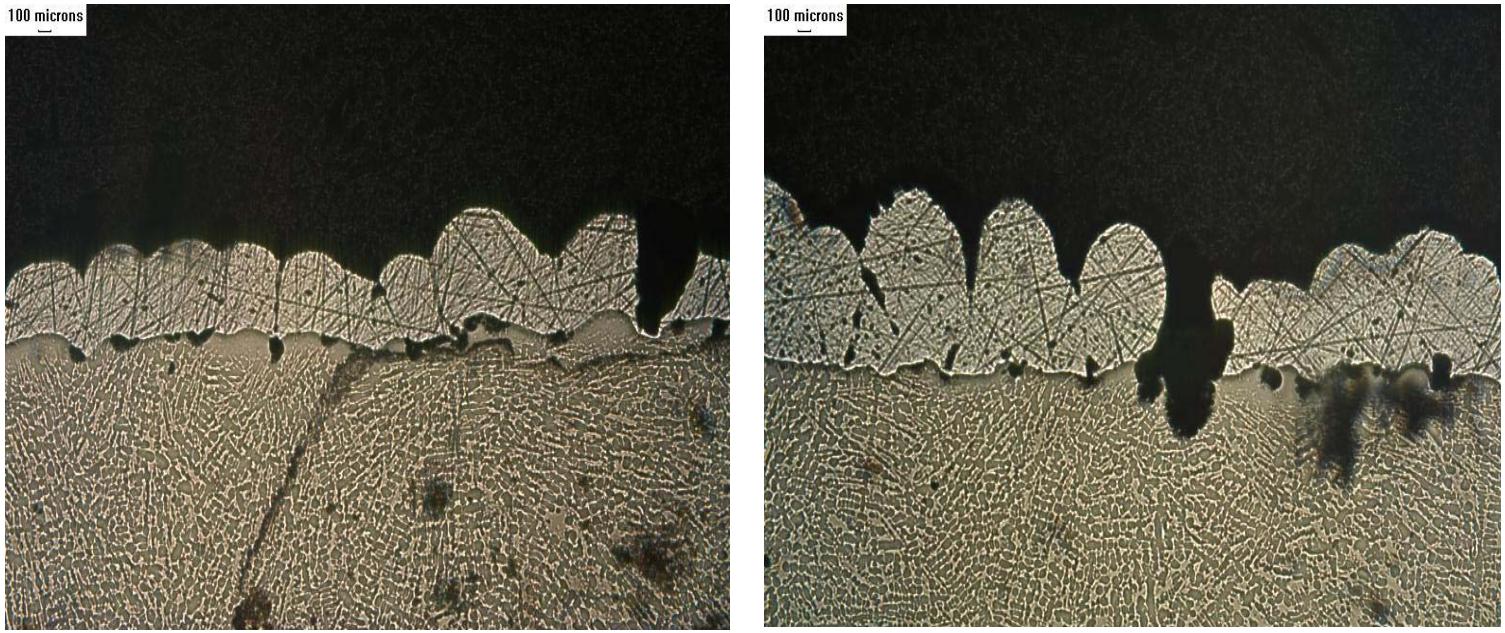


Cutting tool for hard material

Struers Discotom 5

NIKON EPIPHOT 300

Optical microscopic image of conventional paddle coating



3-D Surface Texture Analyzer

Paddles with Different Coating for Field Testing

Coated Paddles Installed in Pug Mill for Field Testing

Milestones and Status

Major Milestones Planned to Date/Status

Planned Milestone	Scheduled	Completed
1: Sample acquisition and characterization	5 samples	8 samples
2. Complete assessment of 3 different surface enhancement methods with different specimens	3 specimens 3 methods	3 specimens 3 methods
3.Process parameter optimization	2 specimens	2 specimens
4.Laboratory testing of wear resistance of coated screens, chain components, and paddles.	paddles	paddles
5.On-site demonstration of surface enhanced screens, chain components, and piping at processing plants.	not scheduled	paddles
6. Economical and technical evaluation	not scheduled	

Key Accomplishments

- **Project Highlights**

Summary of specimens received by March 31, 2004

Company	Qty	Description	Location in Process
The Daniels Co.	6	4” x 4” x ½” AR 400 Steel, Plasma Cut	Washer Bottom Liner
PEAC (Carbontronics)	2	5-1/2” x 5-3/4” Shoes, Thermal Sprayed (Pug mill paddles)	Pug mill
PEAC(Carbontronics)	2	5-1/2” x 5-3/4” Shoes, Plated (Pug mill paddles)	Pug mill
Consol	2	6” x 6” x 1/16” Plates, Torch cut, Used	Clean Coal Silo
Consol	3	6” x 6” x 3/8” Plates, Torch cut, Used	Clean Coal Silo
Tennessee Metallizing	10	¾” x 1” x 1/16” Plates, Thermal Sprayed w/ amorphous coating	Process Testing
Massey	3	10” x 4”x1/4” screens with 5/8” x2” perforations	
Centrifugal and Mechanical Industries	4	Truncated Cone Screens, 22"h x 36.5"b x 11.5"t	Sieving
Cannelton Industries	2	Perforated Plate, ¼” x 48” x 46.5” w/ ¾” x 2” slots	Separation
Carbotronics	2	Pug mill Paddles for immediate processing and return	Pug mill
Carbotronics	6	Pug mill Paddles	Pug mill
Sherman and Reilly (Florida Rocks)	1	3/8” wire screen, 1-3/4 mesh, 12” x 12”, new	Sieving
Sherman and Reilly(Florida Rocks)	1	3/8” wire screen, 1-3/4 mesh, 12” x 12”, worn	Sieving
Tennessee Metallizing	1	2” x 4” x ¼” Steel plate, Thermal sprayed w/ amorphous coating	Process Testing
Gencor Industries Inc.	6	Pug mill Paddles, 5.5" WD x 5.5" LG,450 BHN NIHARD, H2084	Pug mill

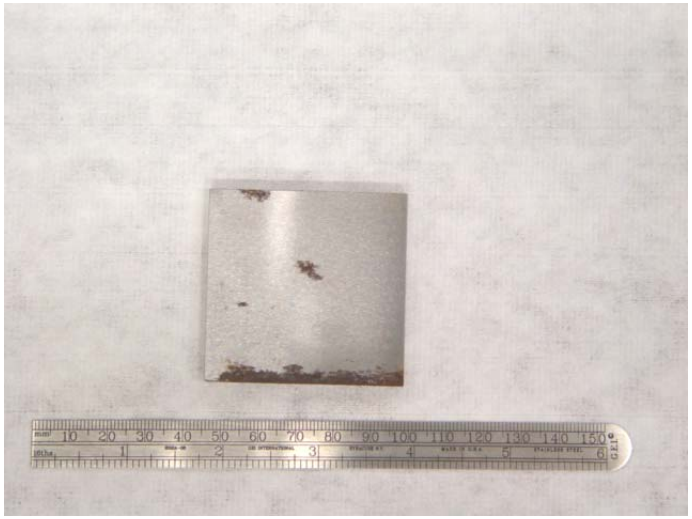
Coating Work in Progress

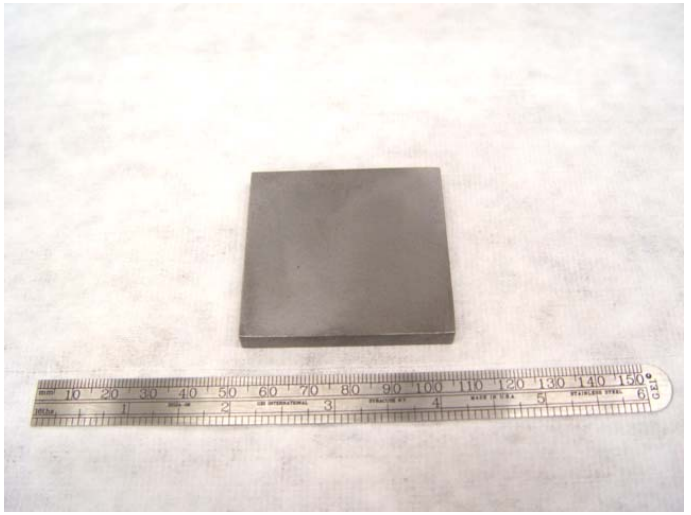
- 2 screens and 6 pug mill paddles will be returned to Oak Ridge from Tennessee Metallizing and Caterpillar Inc., respectively, where they have been deposited with the precursor materials.

- Upon return, these materials will be post-processed by laser processing and HDI processing and then delivered to the University of Kentucky for field-testing.

Coating Process Optimization

Coating Sample Preparation:

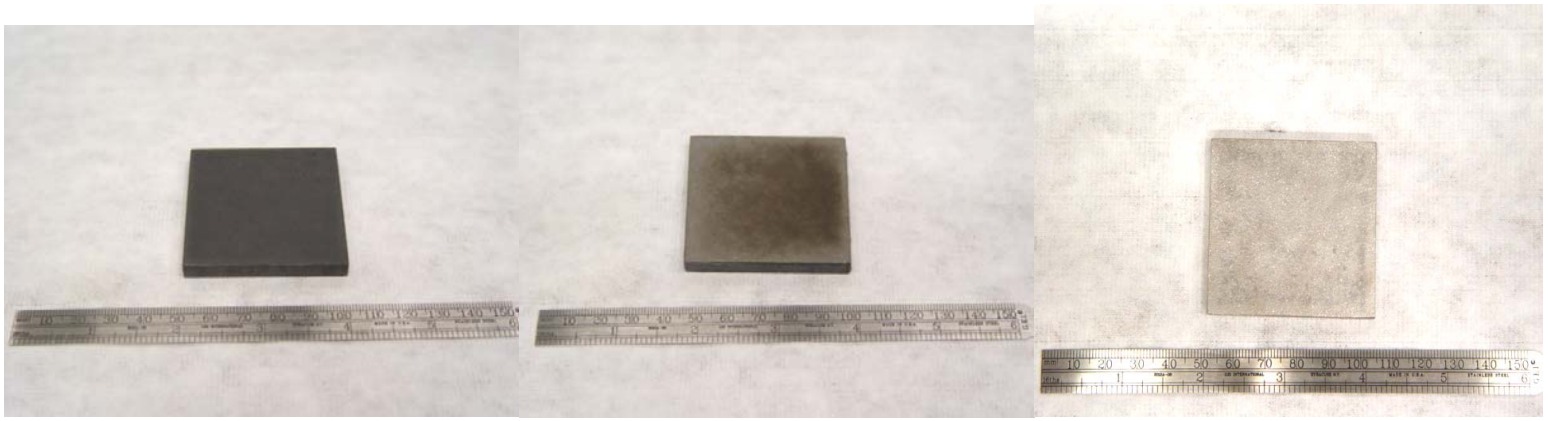




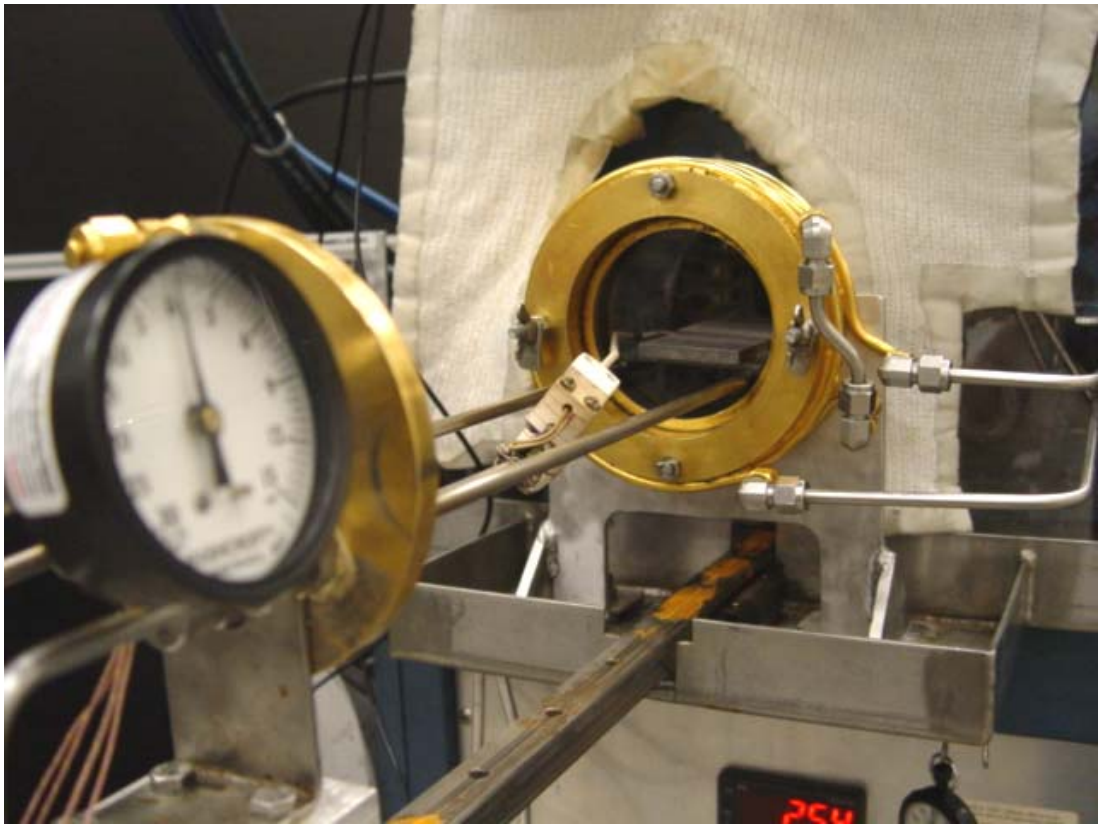
An AISI 4140 coupon shown as received and unprocessed (left);
after sand blasting and wire brushing in preparation for coating (right).

Coating Procedure:

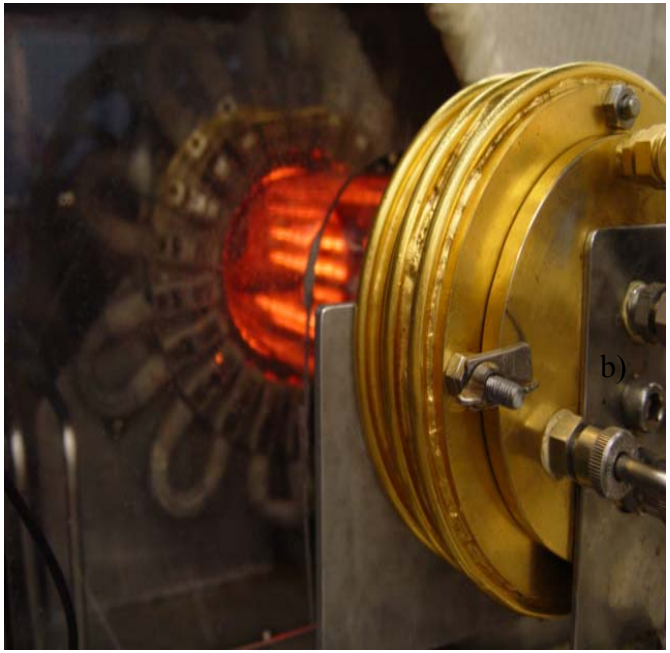
- Room temperature aspirating with a (Ni-10P)-60WC (wt%) coating.
- Coating baking to remove any organic material that was present in the liquid vehicle used to predeposit the precursor material.
- Infrared processing of coating.

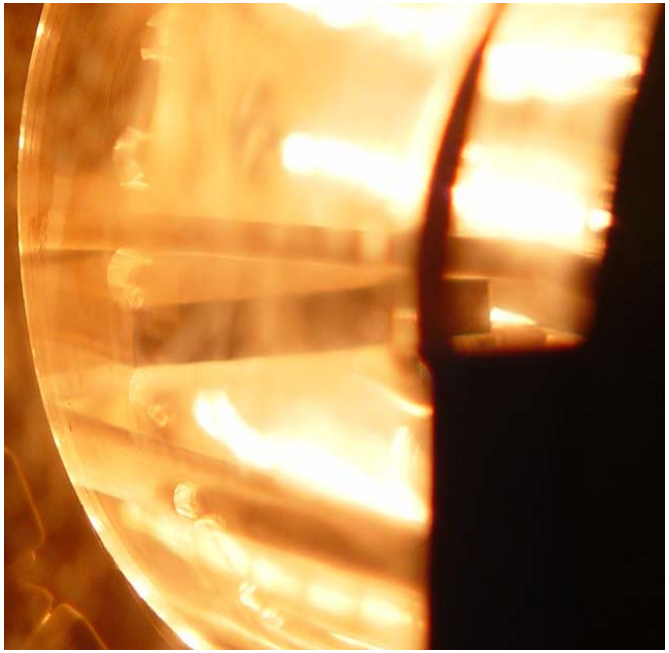


AISI 4140 coupon coated with (Ni-10P)-60WC (wt%) prior to processing (left)
AISI coupon as baked out and ready for HDI processing (middle)
AISI 4140 coupon coated with (Ni-10P)-60WC (wt%) and IR processed (right)



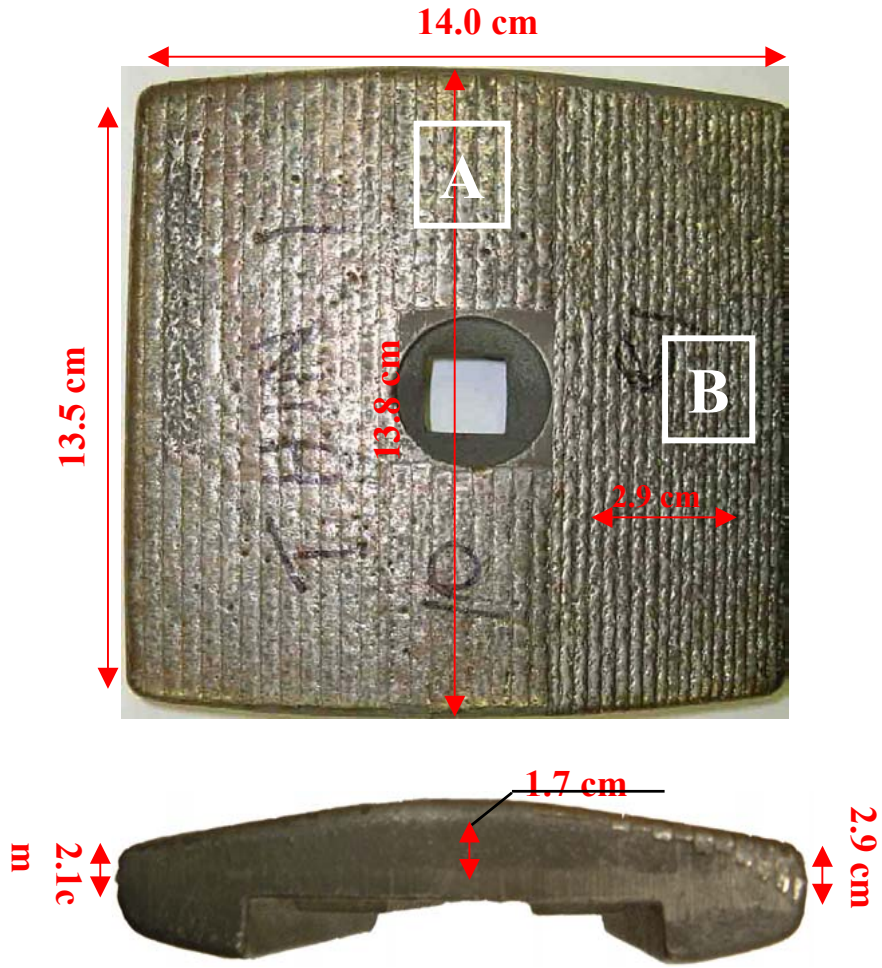
IR furnace in preparation for "baking" out to remove the polymer carrier



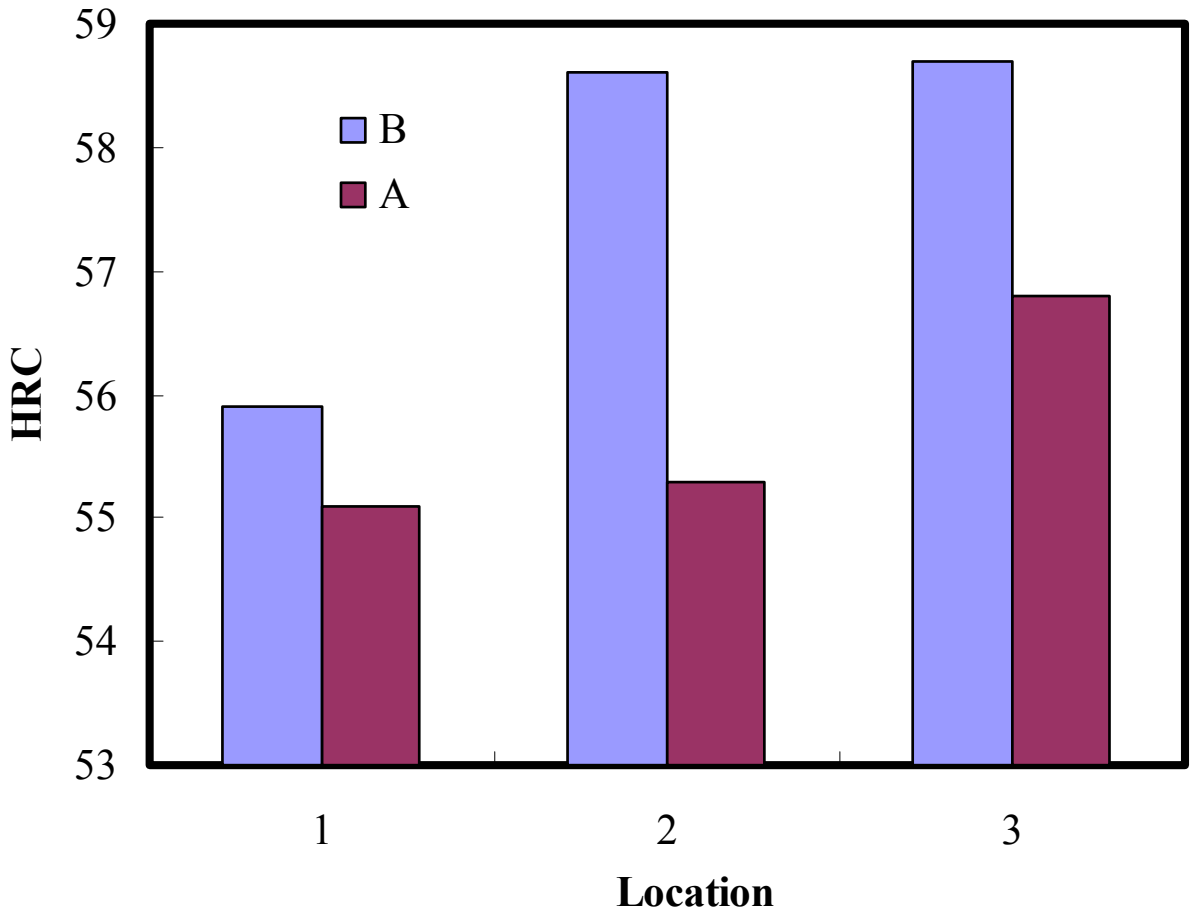


IR furnace loaded with an AISI 4140 coupon coated with (Ni-10P)-60TiC (wt%) during processing (left) and a coupon within the furnace during processing (right).

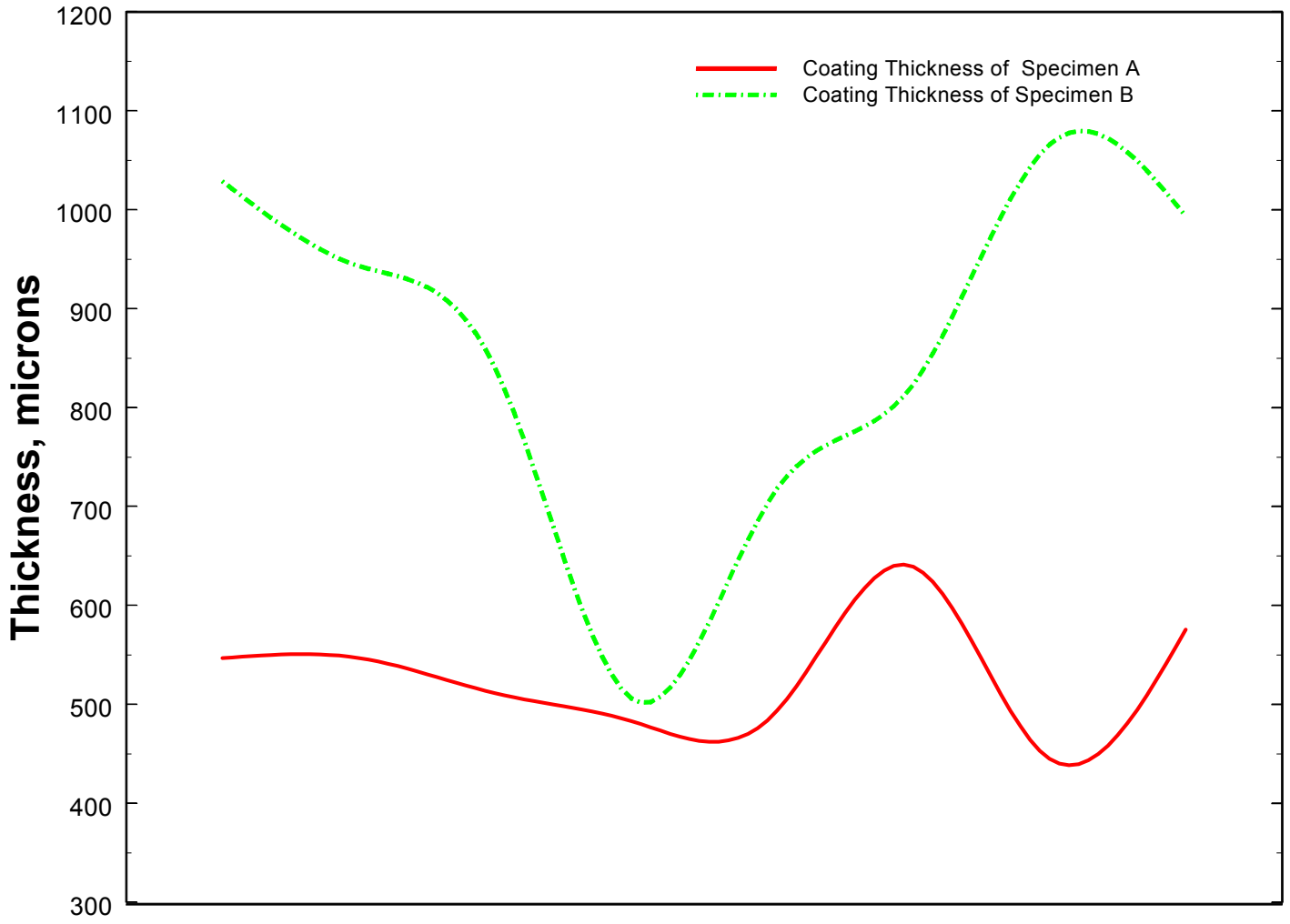
Paddle Specimen Dimension



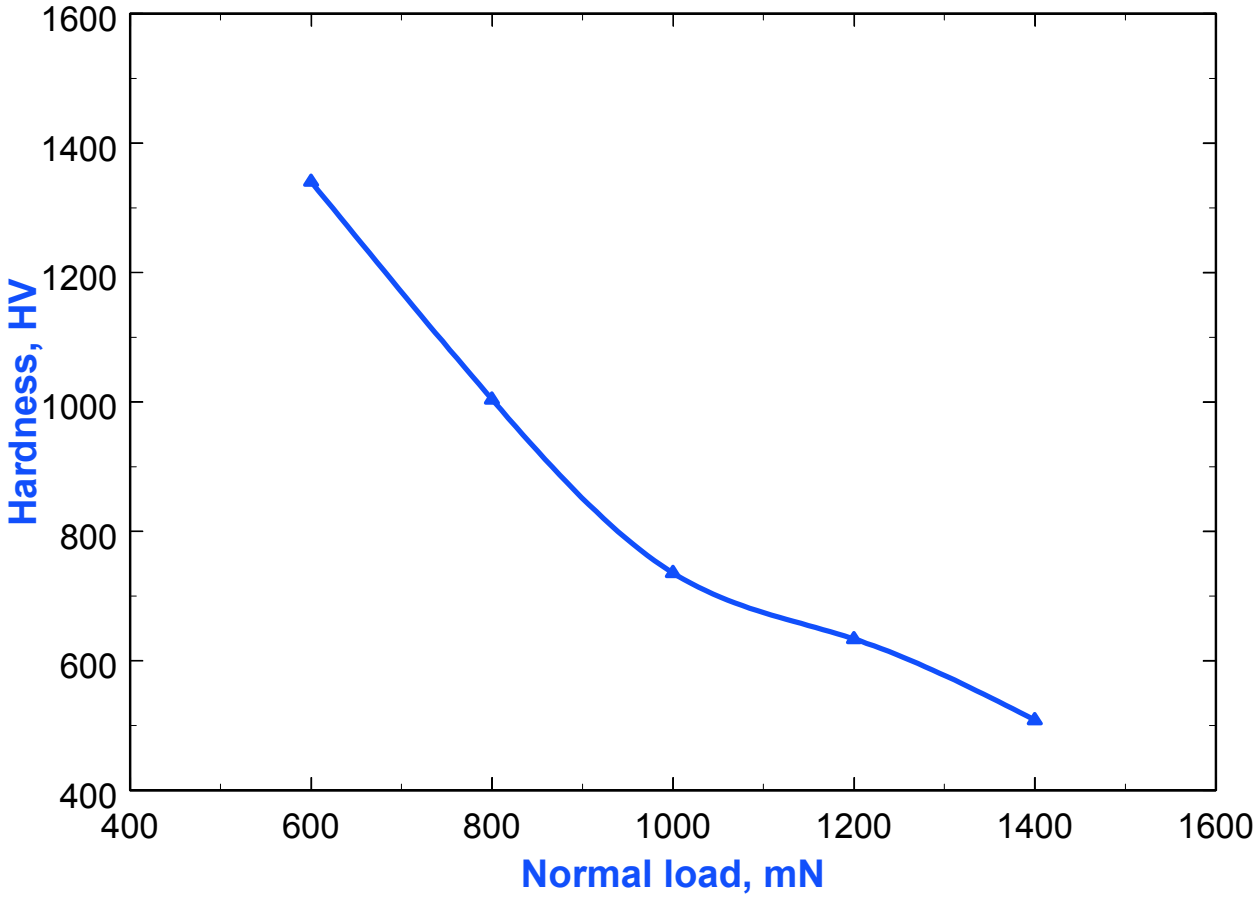
Macrohardness profile of paddles



Coating thickness measurement

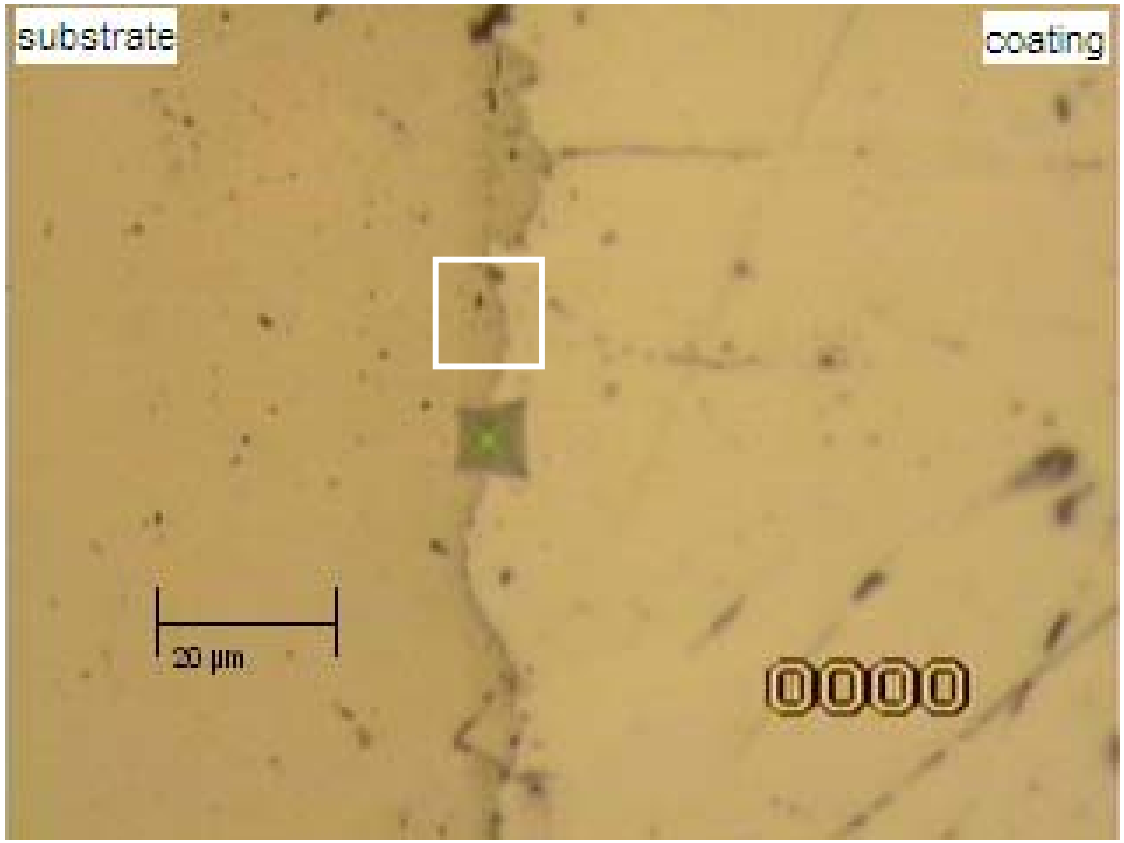


Microhardness testing of coated paddle

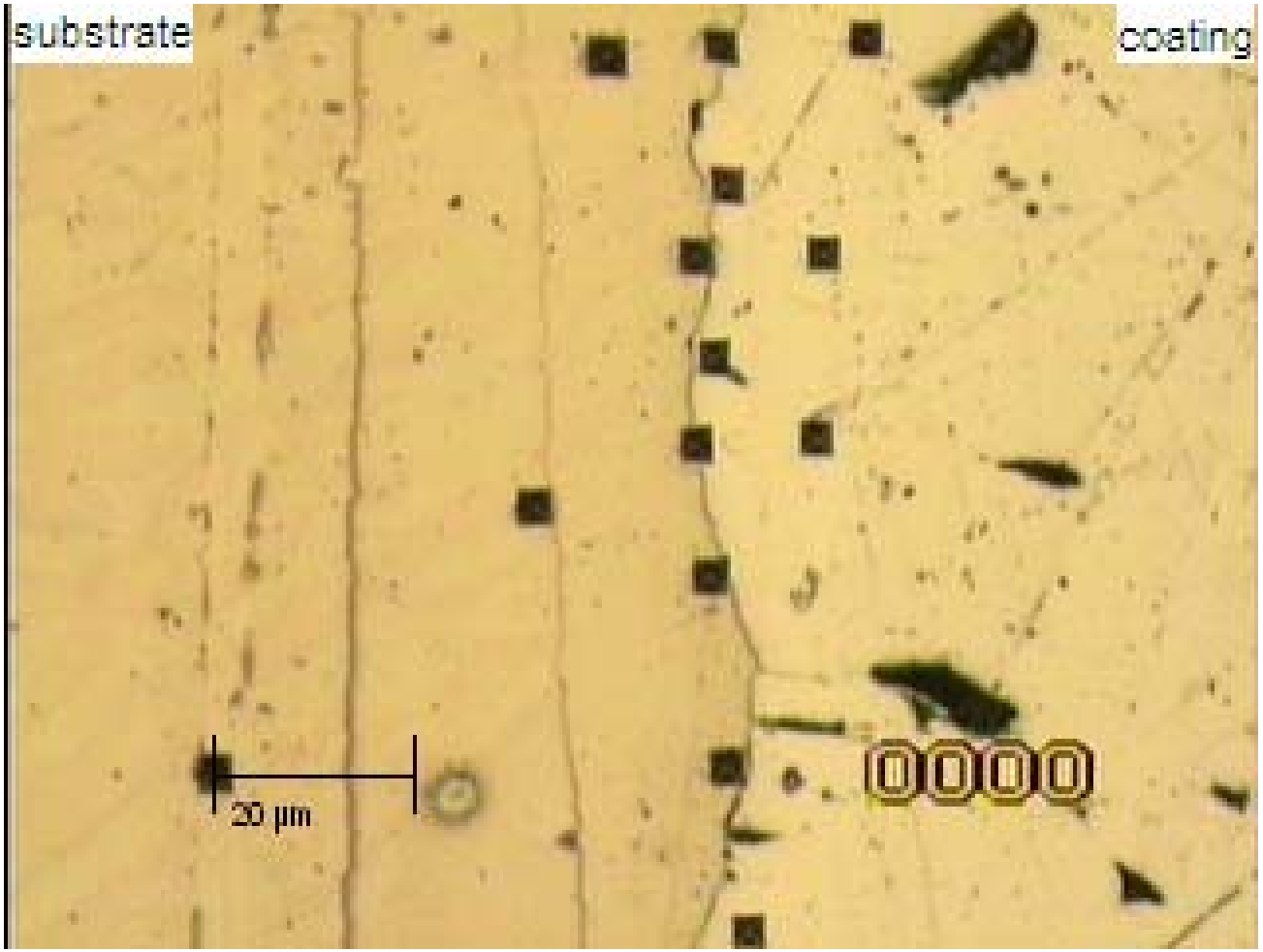


Microhardness testing

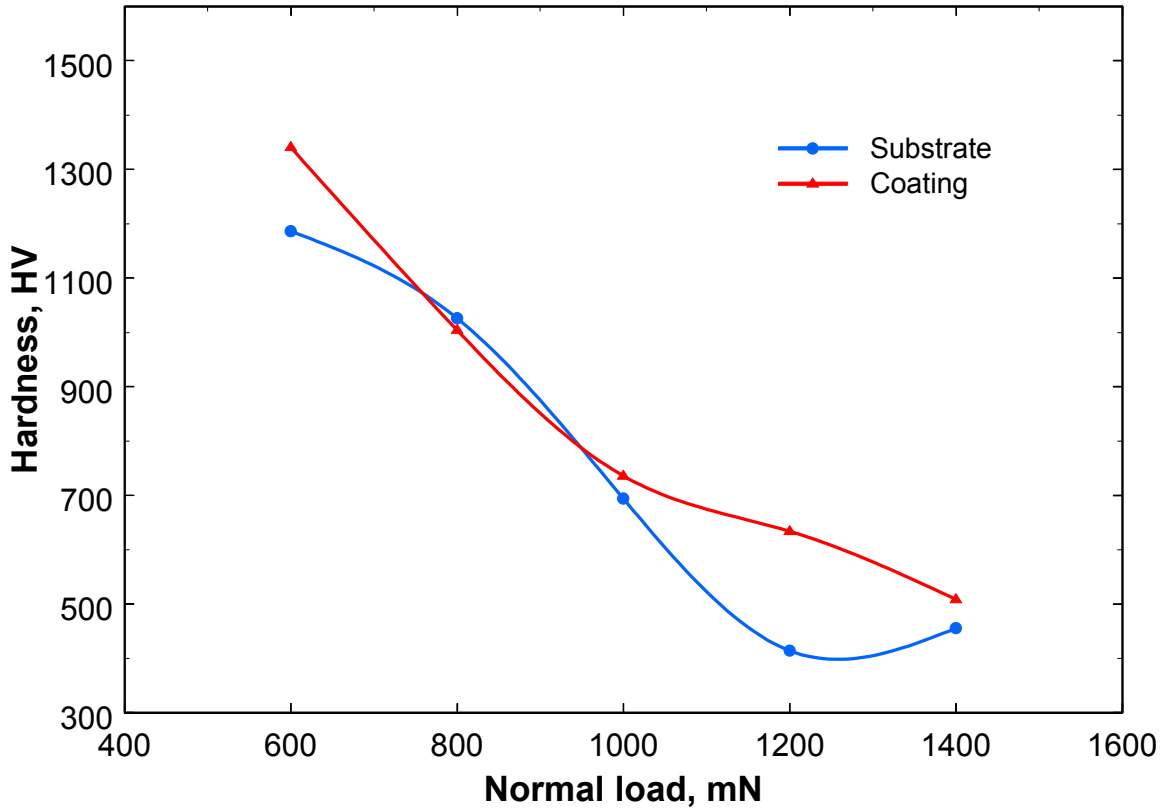
Vickers microhardness indent



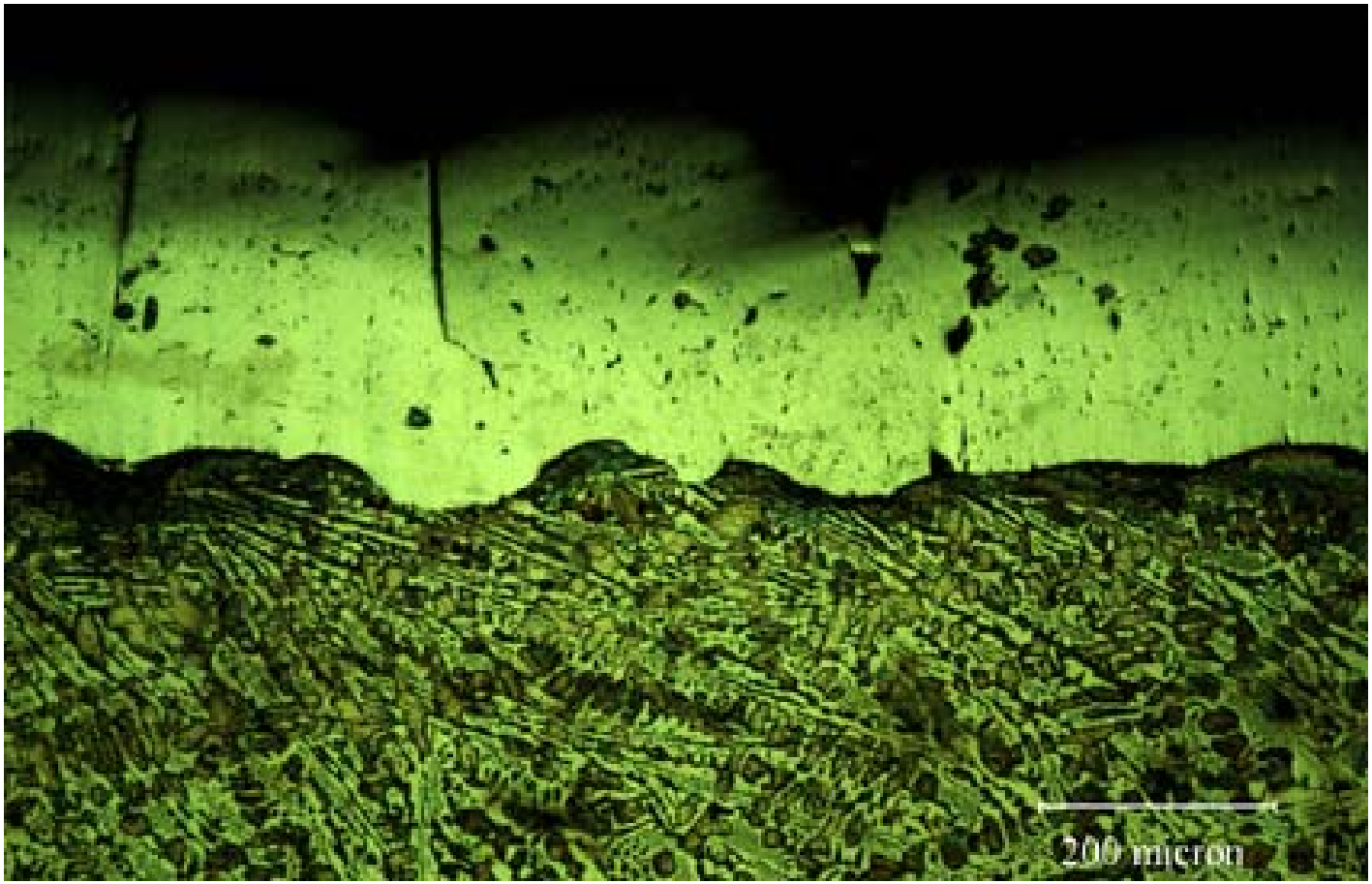
Vickers microhardness indents at interface



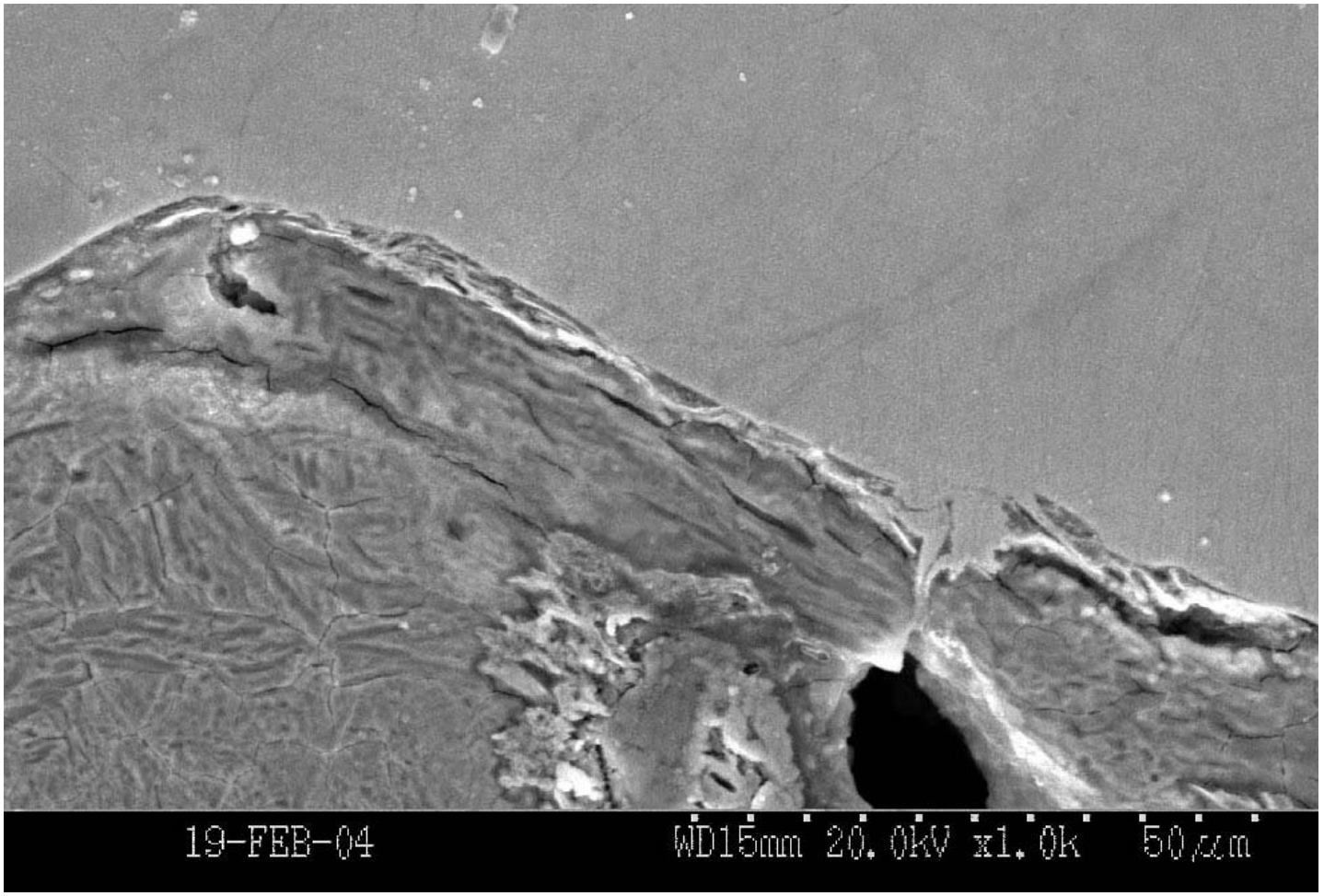
Microhardness of substrate and coating at different normal loads



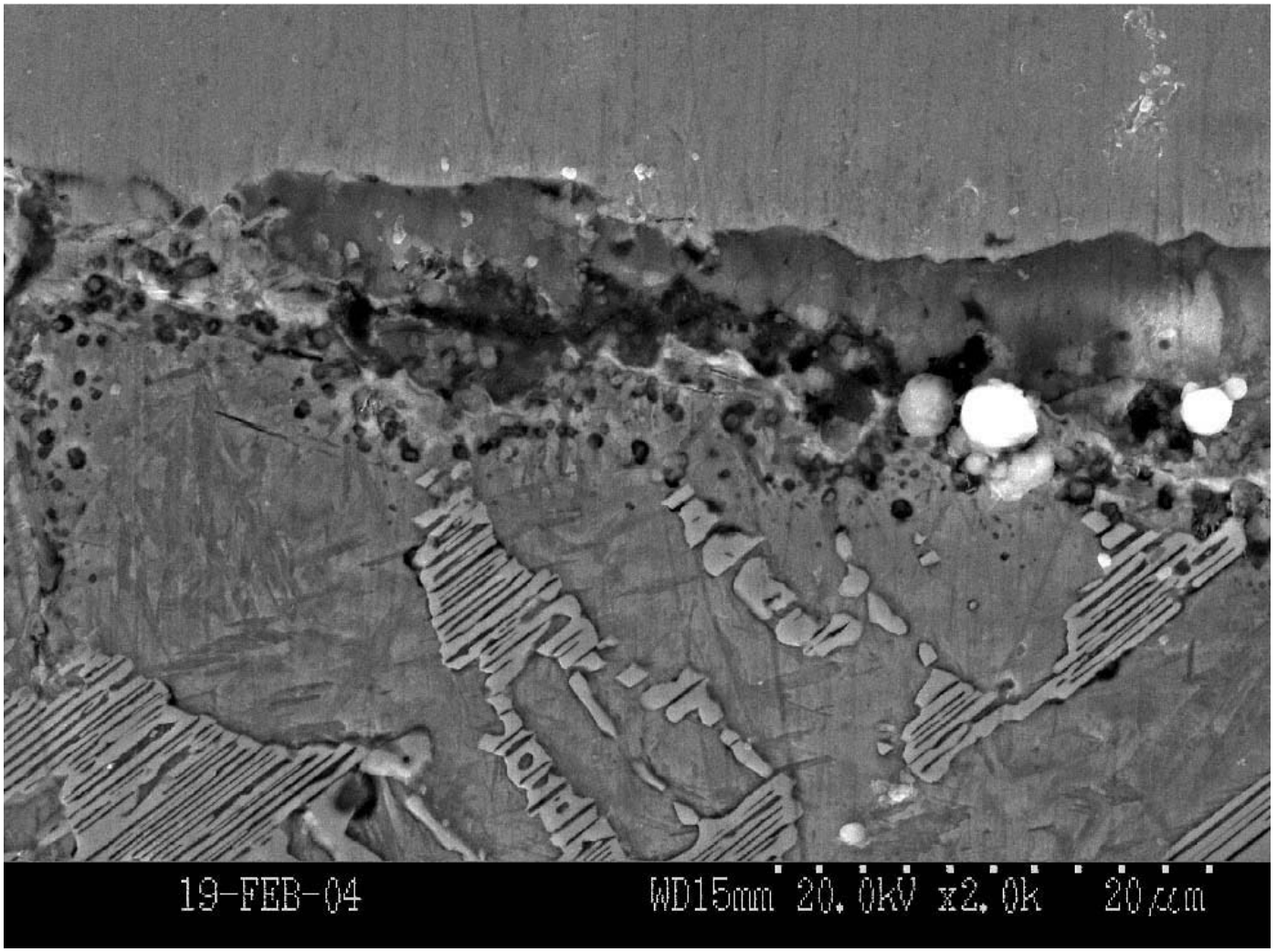
Optical image of specimen at 100×



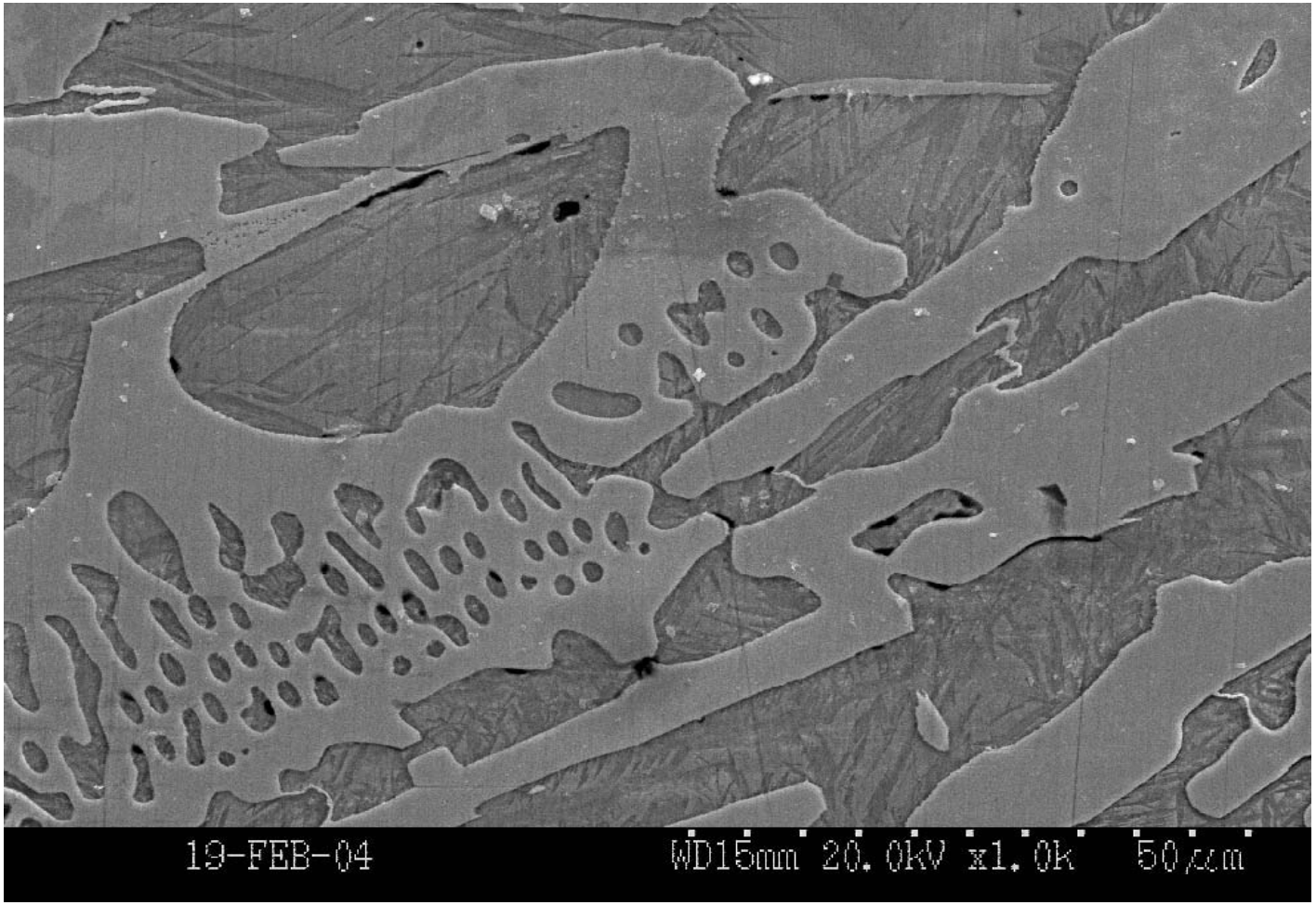
SEM image under magnification of 1000×



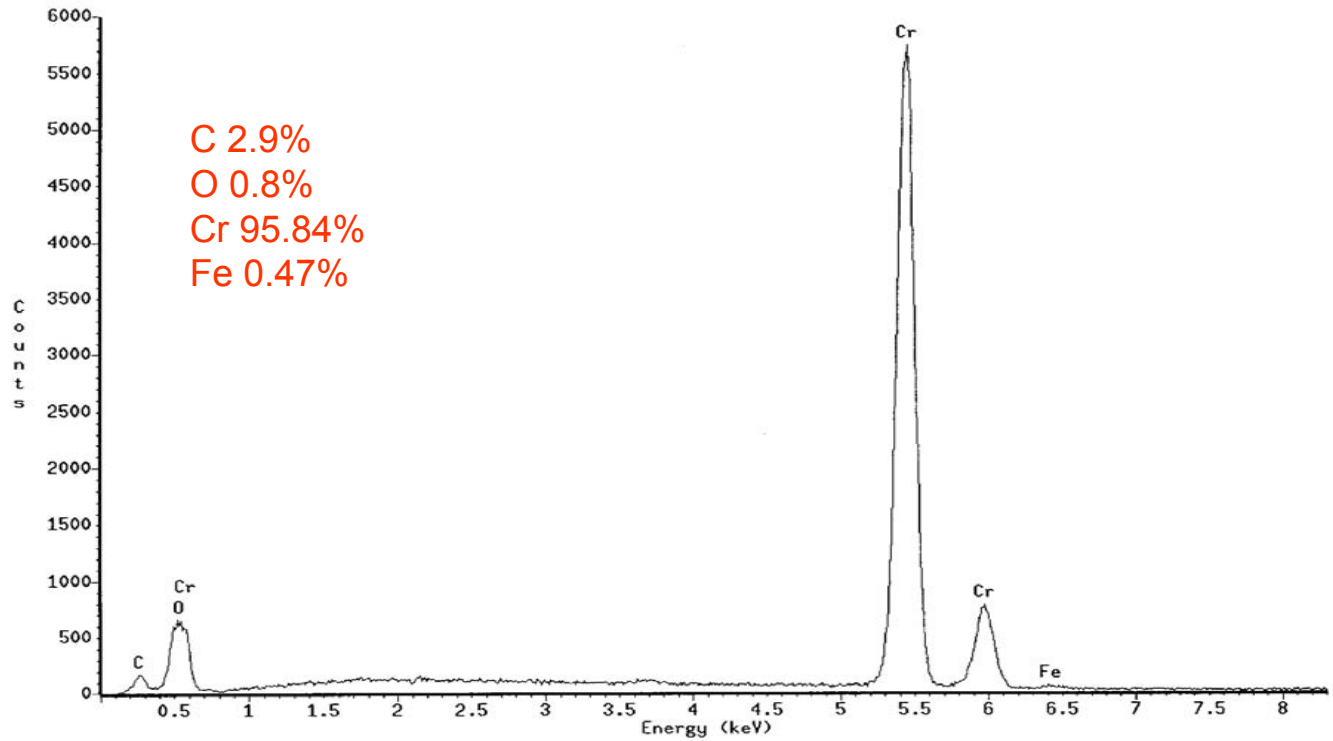
SEM image under magnification of 2000×



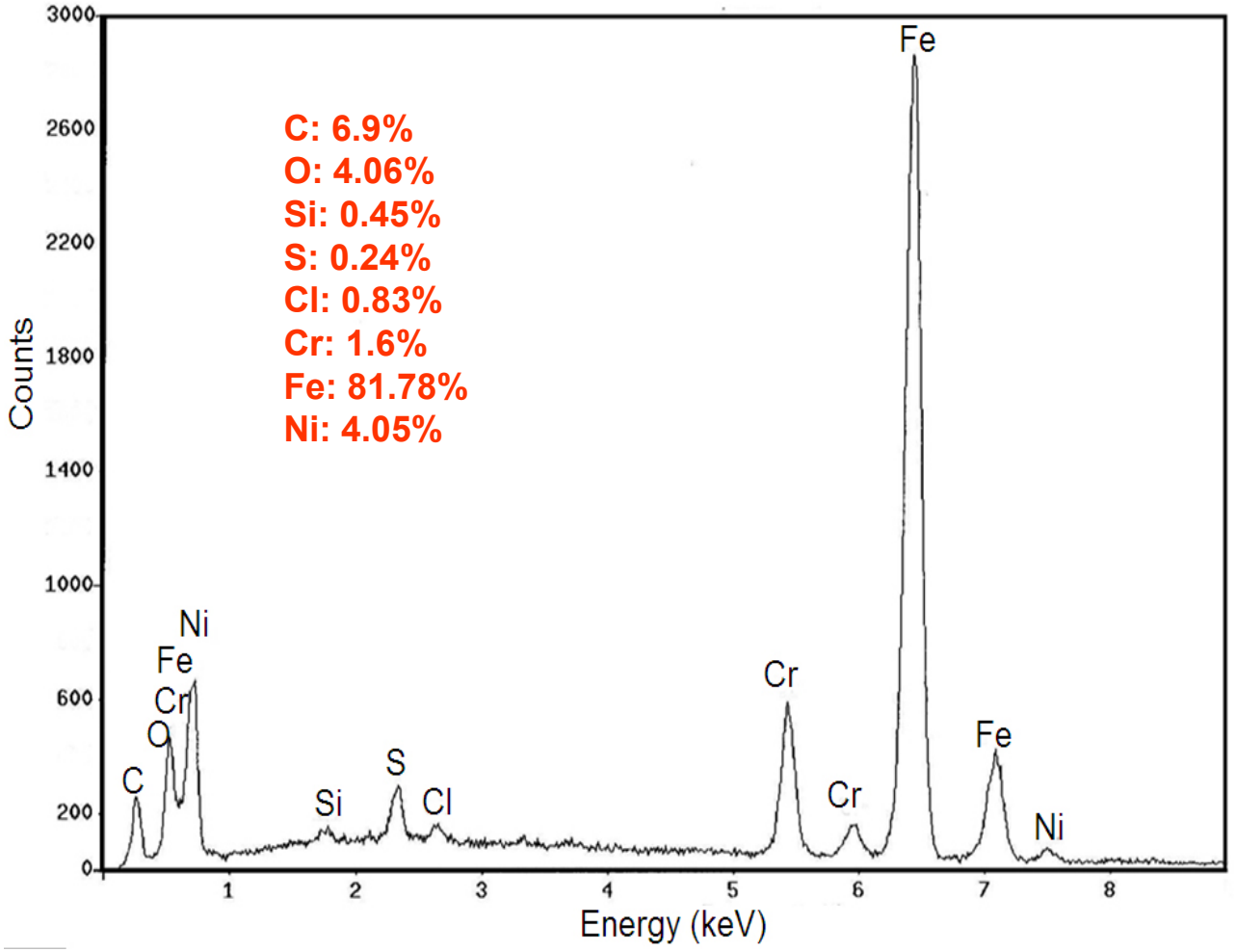
SEM image under magnification of 1000×on substrate



EDS image of specimen coating



EDS image of specimen substrate



Commercialization Outlook

- In-plant testing of coated pug mill paddles will continue at Carbontronics.

- In-plant testing of screens is scheduled to take place this quarter at Massey Energy Inc.!

Use of the GranuFlow™ Process in Coal Preparation Plants to Improve Energy Recovery and Reduce Coal Waste

- **Principal Investigator: David J. Akers**
- **NETL Project Manager:** Joseph Renk
- **Partners:**
  - EME Homer City Generation L.P.
  - PBS Coals Inc.
  - PinnOak Resources, L.L.C.
- **Total Project Cost: $936,612.00**
  - DOE Share: $468,306.00
  - Participant Share: $468,306.00
- **Project Period: 24 months**
- **Project Start Date: July 21, 2003**

Project Objectives

- DEMONSTRATION OF THE GRANUFLOW PROCESS AT COMMERCIAL-SCALE
- PROVIDE THE PERFORMANCE INFORMATION AND EVIDENCE OF OPERABILITY
- NECESSARY TO COMMERCIALIZE THE TECHNOLOGY

Photo Library

Setup tests were performed at PinnOak Resources' Concord (AL) Plant in March 2004.

Milestones and Status

Major Milestones Planned to Date/Status

Planned Milestones	*Scheduled*	*Completed*
• SITE NO. 1		
-- Prepare Test Plan	10/03	10/03
-- Set-Up Test	11/03	
-- Long-Term Test @ Optimum Conditions	01/04	
• SITE NO. 2		
-- Prepare Test Plan	01/04	02/04
-- Set-Up Test	02/04	
-- Long-Term Test @ Optimum Conditions	04/04	
• SITE NO. 3		
-- Prepare Test Plan	03/04	
-- Set-Up Test	05/04	
-- Long-Term Test @ Optimum Conditions	07/04	
• PERFORM EXTENDED DEMONSTRATION	04/05	

Milestones and Status

Key Decision Points Remaining

Decision Point	Scheduled Date	Go/no go
Initial Testing	05/04	
One Week Test	07/04	
One Month Demonstration	04/05	

Key Accomplishments

- PinnOak Resources' Concord Plant (Hueytown, AL) selected as Host Demo Site No. 2. GranuFlow setup tests performed in March/April 2004 at emulsion injection rates of 1 to 3 gpm (0.5% to 1.5%).

- Heritage Research performed bench-scale centrifuge dewatering tests to evaluate emulsions of various types (cationic/anionic) and dosage (0.5% to 2.0%). Anionic HES emulsion selected for commercial demonstration at Concord.

Good News!

- CQ Inc. was successful in acquiring participant cost-share funding through the State of Pennsylvania's Energy Harvest Grant Program to support the GranuFlow Demonstration Project. This grant will cover approximately 20% of estimated total project costs.

Project Recognition

- The GranuFlow Demonstration project was selected in February 2004 for one of 32 grants (out of 139 applications) awarded by the State of Pennsylvania's Energy Harvest Grant Program.

Commercialization Outlook

- GRANUFLOW WILL BE MARKETED UNDER LICENSING AGREEMENT.
- FIRST CUSTOMERS LIKELY TO BE ONE OF THE THREE HOST SITES.
- TECHNOLOGY WILL BE AGGRESSIVELY MARKETED THROUGH EXISTING INDUSTY CONTACTS AND TOURS.

In-Plant Testing of High-Efficiency Hydraulic Separators

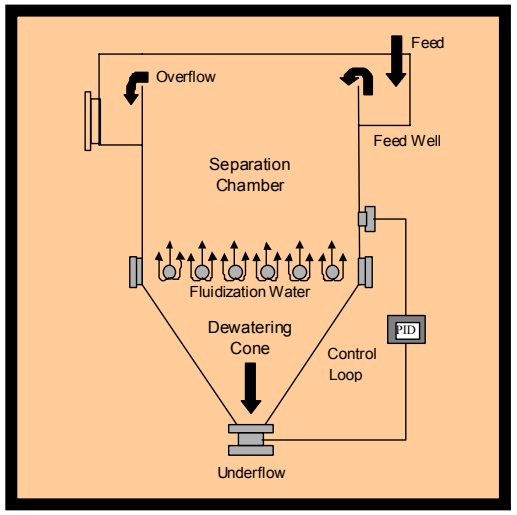
- **Principal Investigator:** Gerald Luttrell, Virginia Polytechnic Institute & State University
- **NETL Project Manager:** Joe Renk
- **Partners:**
  - Eriez Manufacturing, Inc.
  - Dupont Mining Company
  - University of Kentucky
  - TECO Coal Corporation
- **Total Project Cost:** $700,821
  - DOE Share: $345,800
  - Participant Share: $355,021
- **Project Period:** 24 months
- **Project Start Date:** July 30, 2003

Background

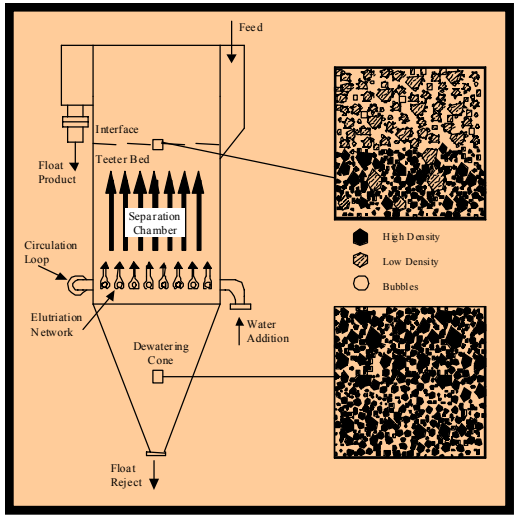
- Technological advances are needed to reduce inefficiencies associated with conventional hydraulic separators.
- In response, a new generation of high-efficiency teeter-bed separators is being developed by the project team.
- These cross-cutting technologies incorporate novel design features that:
  - improve performance (separation efficiency and throughput)
  - reduce operating costs (power demands, water usage, and reagent consumption).

Background

- ***CrossFlow™ Separator***
  - uses a patented tangential feed delivery system and low pressure water distributor
  - greatly improves capacity while simultaneously enhancing sizing efficiency



- ***HydroFloat™ Concentrator***
  - uses a patented air-injected teeter bed
  - combines capacity of a density separator with the flexibility of a flotation process



Project Objective

- Objective: To demonstrate the enhanced capabilities of the ***CrossFlow*** and ***HydroFloat*** technologies for classification/concentration.

- This will be achieved by:
  - further developing these new technologies via systematic testing of key design and operating variables using **pilot-scale separators**
  - demonstrating the improved performance in field trials conducted at an industrial site using a **production-scale prototype**

Milestones (Phase I – Pilot-Scale Tests)

Milestone	Target Date	Status
1 - Phase I Planning	July 03	Planning Completed, Kickoff Meeting at Eriez Completed on Sept. 15, 2003
2 - Field Testing	Apr 04	Fabrication of Two Test Units Completed (One Coal and One Mineral), Field Tests Are Continuing at Coal and Mineral Sites
3 – Evaluation	May 04	Test Data Has Been Compiled, Mass Balanced and Evaluated for Tests Conducted at Phosphate and Coal Processing Facilities
4 - Sample Analysis	May 04	Laboratory Analyses (Ash & Float-Sink) Underway for New Samples Obtained From Comparison Testing at a Coal Plants
5 - Phase I Report	June 04	--- ---

Milestones (Phase II – Prototype Tests)

Milestone	Target Date	Status
6 - Phase II Planning	July 04	--- ---
7 – Scale-Up Design	Oct 04	--- ---
8 – Commissioning	Jan 05	--- ---
9 – Detailed Testing	May 05	--- ---
10 – Detailed Evaluation	May 05	--- ---
11 - Final Report	June 05	--- ---

Accomplishments

- **CrossFlow** tests have been conducted at several coal preparation facilities located in the eastern U.S.
- These include:
  - **KenAmerica Plant**, Ohio Valley Coal Company
  - **Federal Plant**, Eastern Associated Coal
  - **Ohio Valley Plant**, Ohio Valley Coal Company

Accomplishments

- **KenAmerica Plant, Ohio Valley Coal Company**
  - CrossFlow was selected over spirals and water-only cyclones for use at the new KenAmerica plant.
  - The plant will service the Paradise mine located near Central City in western Kentucky.
  - The CrossFlow will be used to treat intermediate size coal in the 1 x 0.15 mm size range.
  - The company has already agreed to purchase full-scale prototype for this project.
  - Installation of the full-scale prototype is expected to be completed this summer.

Accomplishments

- **Federal Plant, Eastern Associated Coal Company**
  - CrossFlow evaluated as a replacement for existing water-only cyclones at the Federal plant located outside Morgantown, West Virginia.
  - Existing circuit requires three stages of cleaning to obtain a suitable clean coal ash content.
  - Test data show that a single pass through the CrossFlow provided better recoveries at comparable clean coal qualities.
  - Company is currently reviewing proposal to purchase full-scale prototype for this project.

Accomplishments

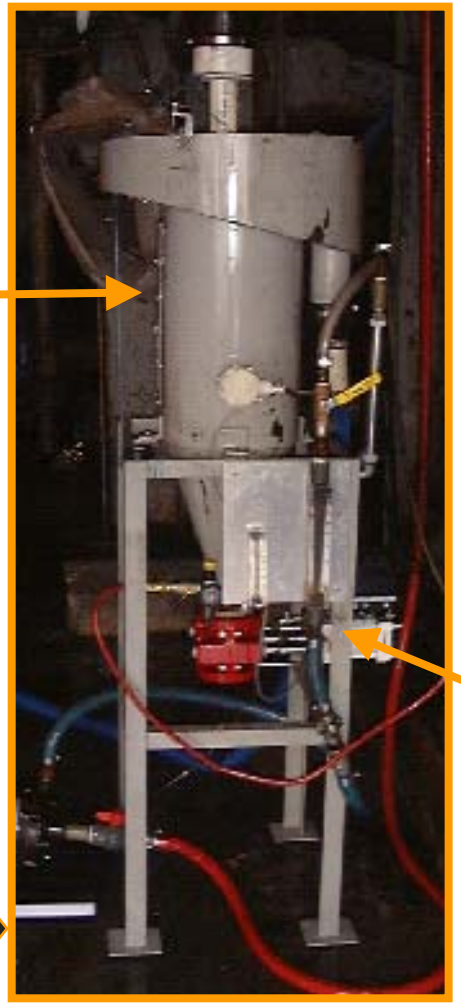
- **Ohio Valley Plant, Ohio Valley Coal Company**
  - CrossFlow evaluated as a replacement for an existing single-stage spiral circuit at the Ohio Valley plant near Alledonia, Ohio.
  - Test samples collected from the test unit (5 sets of samples) and existing spirals (1 set of samples).
  - All 6 sets of samples are currently being analyzed to determine size-by-size ash and solids contents.
  - The best samples from each process will be subjected to float-sink tests this quarter.
  - Company has agreed to purchase full-scale prototype for this project provided that the CrossFlow outperforms the existing spiral circuit.

Accomplishments

- **HydroFloat** tests completed for Cargill Fertilizer, a major Florida phosphate producer.
- HydroFloat achieved superior recoveries of coarse particles compared to conventional cells.
- Cargill has agreed to purchase a prototype unit for testing against existing flotation cells in the coarse recovery circuit.
- Installation of the prototype is expected during July.

Photo Library

Viewing window in the CrossFlow unit showing upper (coal) and lower (rock) particle separation.

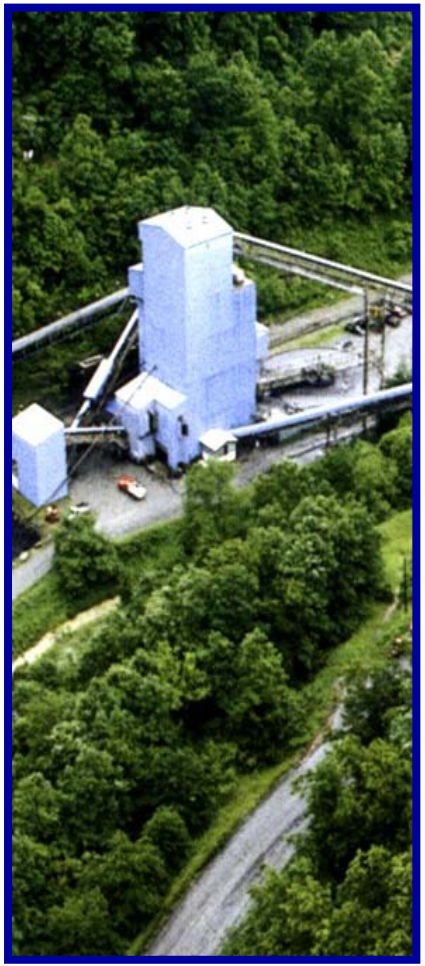


CrossFlow unit used to conduct in-plant coal cleaning test work.

Control instruments and discharge value mounted on the CrossFlow unit.

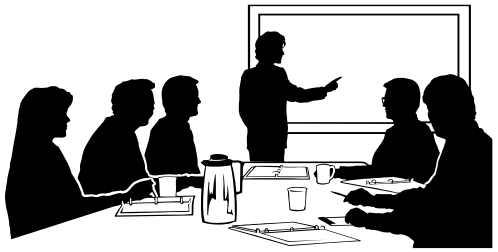
Good News!

- Due to high demand, a second test unit has been commissioned for this project.
  - Unit #1: Mineral Applications
  - Unit #2: Coal Applications
- Unit #1 Schedule for Minerals
  - Dupont Site (Mineral Sands): April/May
  - Iluka Site (Mineral Sands): April/May
  - IMC Site (Phosphate): Not yet scheduled.
- Unit #2 Schedule for Coal
  - Arch Site #1 (Coal): April/May
  - Arch Site #2 (Coal): April/May
  - TECO Site (Coal): April/May



Recognition

- To date, no technical papers or presentations have been made in association with this project.
- Several technical presentations are planned as the test data become available.



Commercialization

- **Eriez Manufacturing**
  - As planned, commercialization of the new technologies is being pushed ahead by the equipment manufacturer.
  - Eriez provides an excellent network of sales executives and distributors throughout the U.S. and abroad.
  - Eriez management expects to make a profit this year from the sale of the prototype units.

- **Virginia Tech & University of Kentucky**
  - The academic team members assist commercialization by providing field testing, data analysis, and analytical services.
  - Universities provide technology transfer by disseminating project findings (e.g., reports, publications, presentations, workshops, seminars, and training activities).

Reducing Energy Costs at Limestone Quarries

- **Principal Investigator:** DOE/NETL
- **NETL Project Manager:** Mike Mosser
- **Partners:** Maryland Power Plant Research Program; Subtechnical, Inc.; Martin Limestone, Inc.; Keystone Lime Co., Inc.
- **Total Project Cost:** **$200,000**
  - DOE Share: $300,000
  - Participant Share: $120,000
- **Project Period:** **24 months**
  - Project Start Date: 6/1/03

Project Objectives

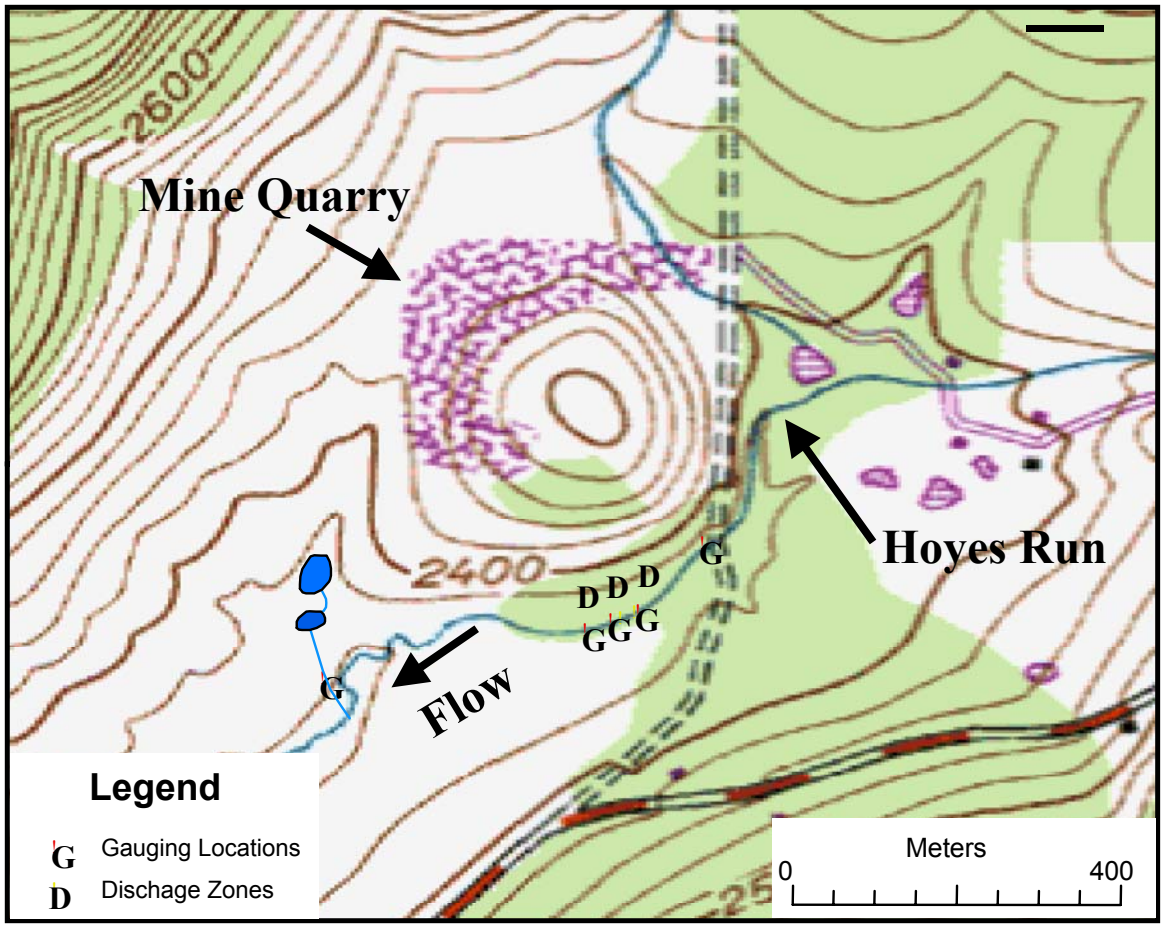
- To reduce energy consumption in the form of dewatering costs at limestone quarries. These costs result from the interconnection of quarries and streams through solution cavities. These cavities will be delineated using geophysical techniques and be targeted to received grout – both conventional and grout containing coal combustion products (CCP). As a result, the project will reduce energy costs for pumping water, minimize the environmental impact on streams, help prevent sinkhole formation, and provide a beneficial use for CCP.

Two Sites Selected for Study

Hoyes Run Quarry
Garret County, MD
Keystone Lime Co., Inc

Burkholder Quarry
Lancaster County, PA
Martin Limestone, Inc

Map of the Hoyes Run Quarry Area



Hoyes Run Quarry

Completed Milestones

- Stream gauging determined areas of water loss
- Pre-grout geophysical surveys
  - conductivity - EM 34 & EM 31
  - resistivity - 2D
- Injection of polyurethane grout in stream bed
- Post-grout geophysical surveys
  - conductivity - EM 34

Conclusions

- Pre-grout resistivity identified void areas
- Grouting did not significantly affect flow into quarry
- Post-grout EM 34 survey did not detect grout

Hoyes Run Quarry

Work Completed this Quarter

- Post-grout geophysical surveys
    - resistivity - 3D (Super Sting)
- Meeting with quarry personnel

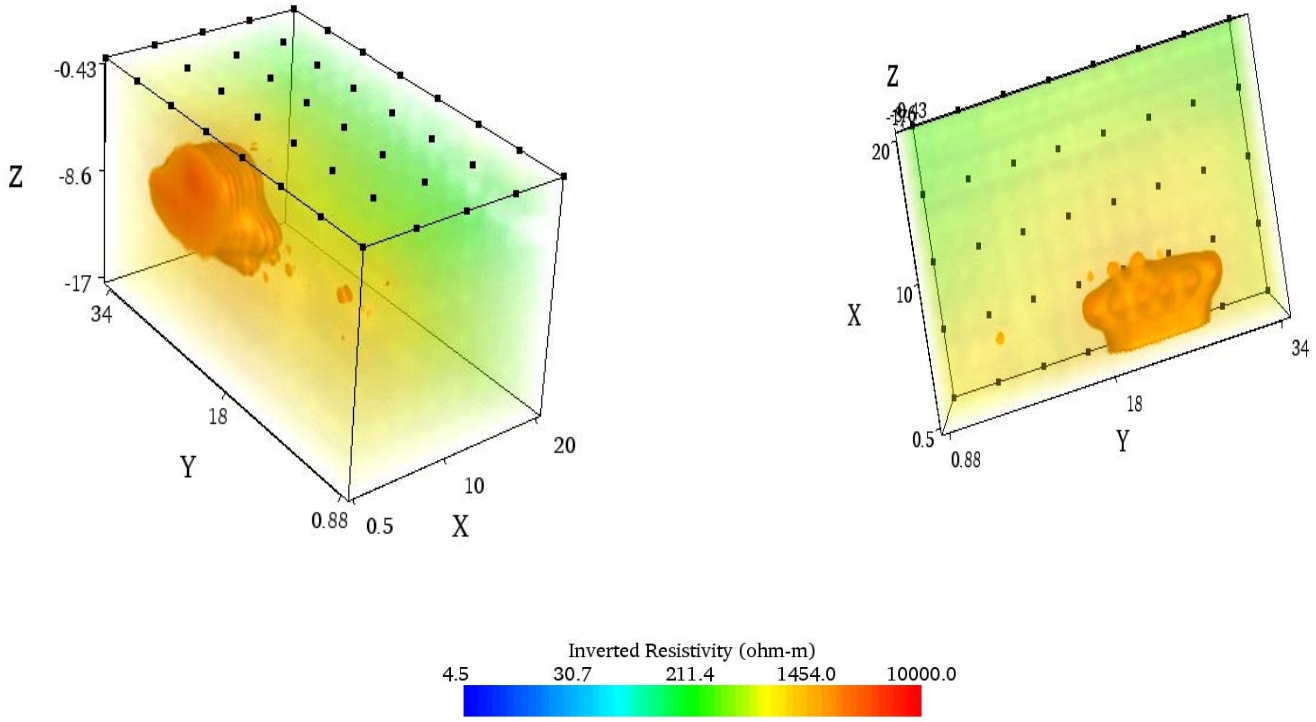
Conclusions

- Post-grout resistivity detected grout under and on both sides of stream.
- Keystone Lime Co., Inc. agreed to keep detailed pumping records to quantify water pumped, drill holes for additional grouting.

Hoyes Run Quarry

3D Resistivity Survey using Super Sting

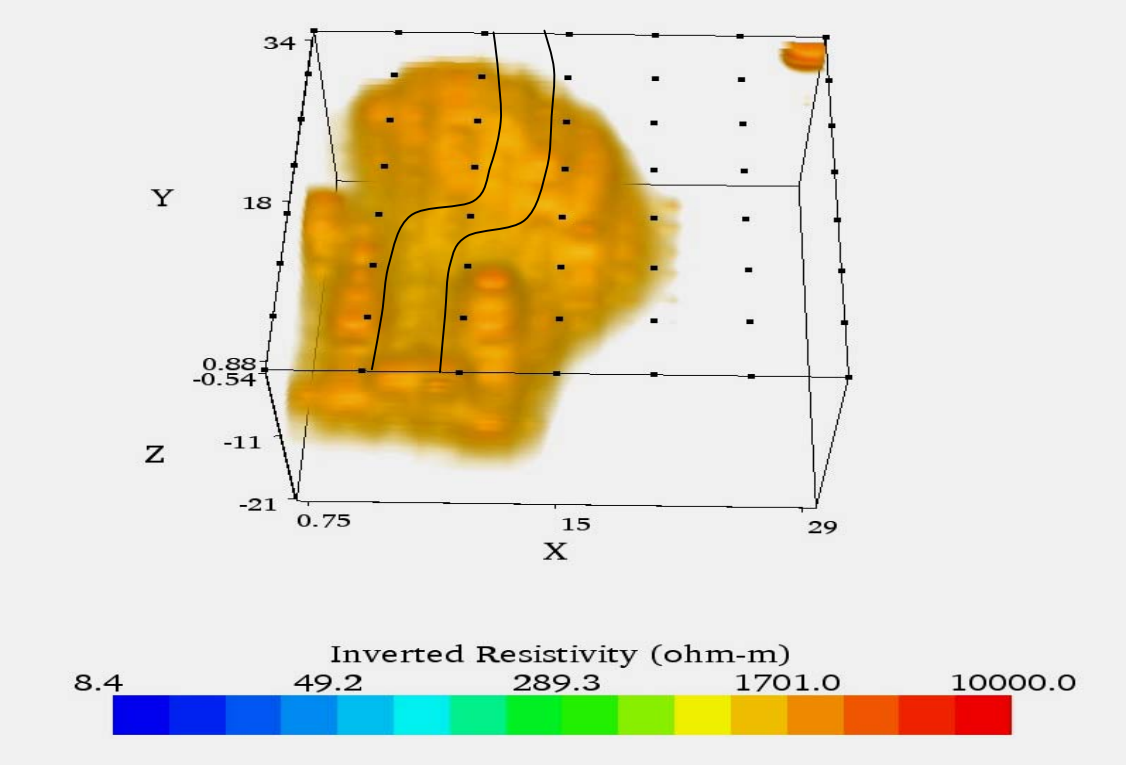
Hoyes Run Quarry



3D Images North of Stream (Stream approx. at X = 0)

Highly resistive area (in orange) appears to be polyurethane grout

Hoyes Run Quarry



Second, Expanded Resistivity Survey

3D images under stream (position of stream shown on figure).

Highly resistive area (in orange) identified grouted area on both sides of stream

Hoyes Run Quarry

Scheduled Work for Next Quarter

- Continue to quantify water pumped based on pumping records
- Finalize CRADA with Keystone Lime Co., Inc.

Hoyes Run Quarry

Key Accomplishments

- Confirmed connectivity between Hoyes Run and quarry pit using dye tracer
- Determine zones of stream loss by stream gauging
- Pre-grout geophysical techniques applied in area
    - Conductivity survey completed using EM 31 and EM 34
    - preliminary 3-D resistivity survey performed
- Approximately 30 m of stream was grouted with polyurethane grout
- Post-grout EM-34 survey was unable to identify grout
- Post-grout stream gauging was inconclusive due to high water flow
- 3-D resistivity data from two separate surveys using the Super Sting R8 Resistivity System identified polyurethane grouted area
- Keystone Lime Co., Inc. willing to contribute to project

Aerial View of the Burkholder Quarry

Burkholder Quarry

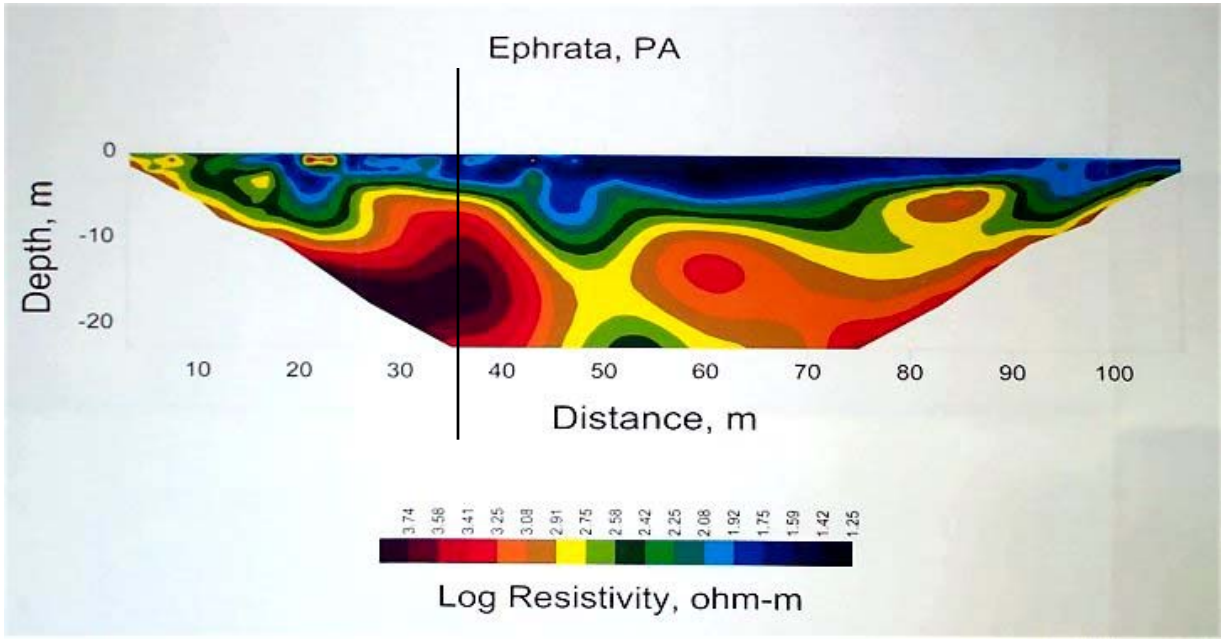
Completed Milestones

- Tracer tests
- 2D resistivity geophysical survey between river and quarry
- Drilling to confirm results of resistivity survey

Conclusions

- Tracer tests confirmed connection between Conestoga River and quarry
- Resistivity survey identified void areas
- Drilling confirmed resistivity results and connection to stream
  - two catfish were blown from one of the drill holes while air was injected to an adjacent hole

Burkholder Quarry



Hole 3A log

0-4 m	clay
4-7 m	rock (hit water at 7 m)
7-15 m	opening – drill bit moved through this area very easily. Driller said it's hard to say if there is any material in this area.
>15 m	rock

Burkholder Quarry

Work Completed this Quarter

- Meeting with quarry personnel
- Site visit
- Determined electric pumping costs over past 6 years exceeded $275,000

Conclusions

- Martin Limestone, Inc. agreed to continue to supply detailed pumping records and help quantify water pumped, they are also willing to drill additional holes for confirmation of voids and grouting, aid in the interpretation of geophysical surveys and consider the implementation of a grouting plan and help us determine its success.

Burkholder Quarry

Scheduled Work for Next Quarter

- Continue to quantify water pumped based on pumping records
- Perform ~3500-ft-long 2D resistivity survey
- Finalize CRADA with Martin Limestone, Inc.

Burkholder Quarry

Key Accomplishments

- Confirmed connectivity between Conestoga River and quarry pit using dye tracer
- 2D resistivity geophysical survey along road completed
- Drilling confirmed results of resistivity survey and connectivity of river and quarry
- Martin Limestone, Inc. willing to contribute to project

Milestones and Status

Major Milestones Planned to Date/Status

Planned Milestone	*Scheduled*	*Completed*
– Development/evaluation of resistivity techniques	7/03	7/03 Ongoing
– Evaluation electromagnetic techniques	7/03	7/03 Ongoing
– Conduct field-scale demonstrations of grouting	8/03	7/03
– Establish CRADAs with three industry partners	10/03	Ongoing
– Initiate data gathering for pumping/ancillary costs	12/03	3/04 Ongoing
– Select quarries to demonstrate grouting	2/04	1/04

Milestones and Status

Major Milestones Planned to Date/Status

Planned Milestone	*Scheduled*	*Completed*
– Expand area of 3D survey at Hoyes Quarry	2/04	3/04
– Perform long 2D resistivity survey at Burkholder	3/04	4/04
– Perform detailed 3D resistivity survey at Burkholder	3/04	
– Develop costs associated with ancillary problems	4/04	4/04
– Complete grout formulation work	5/04	
– Conduct full-scale demonstration	9/04	
– Evaluate effectiveness of demonstration	11/04	
– Generate final draft report	12/04	

Optimized Charge Motion and Slurry Flow in Plant Scale SAG Mills

- **Principal Investigator:** Raj K. Rajamani
- **NETL Project Manager:** Mike Mosser
- **Partners:**
  - University of Utah, Kennecott Utah Copper Corporation, Cortez Gold Mines, Process Engineering Resources, Inc., Outokumpu Technology Inc., Weir Rubber Engineering

- **Total Project Cost:** $913,480.00
  - DOE Share: $383,480
  - Participant Share: $530,000

- **Project Period:** 24 months
- **Project Start Date:** August 1, 2003

Project Objectives

- **PILOT MILL STUDY OF INDIVIDUAL VARIABLES:**
  - **Charge Filling**
  - **Lifter Configuration**
  - **Discharge Grate**
- **COLLECT OPERATIONAL DATA (KUCC & CORTEZ)**
- **DEVELOP AN INTEGRATED PROCESS MODEL TO INCREASE SAG MILL EFFICENCY**

Photo Library

Cortez Gold Mines Crash Stop Survey – I
8 Oct 2003

Photo Library

Cortez Gold Mines Crash Stop Survey - I
(Measuring shell lifter profile)

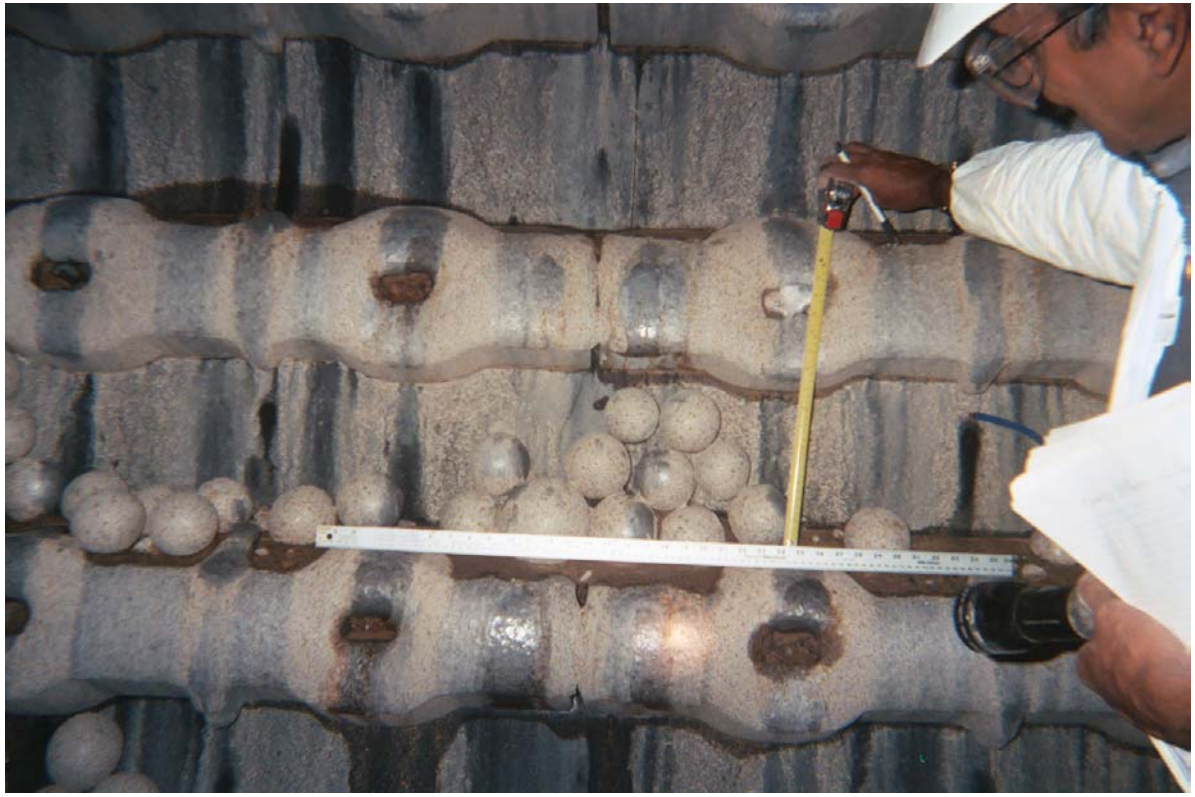


Photo Library

Cortez Gold Mines Crash Stop Survey - I
(Pulp Lifter view from mill discharge)

Photo Library

Cortez Gold Mines Crash Stop Survey - I
(Charge inside the mill)

Photo Library

Cortez Gold Mines Crash Stop Survey – II
3 March 2004

Photo Library

Cortez Gold Mines Crash Stop Survey - II
(Measuring shell lifter profile)

Photo Library

Cortez Gold Mines Crash Stop Survey - II
(Packing and slurry poll inside the mill)

Photo Library

Cortez Gold Mines Crash Stop Survey - II
(Wear on pulp lifters)

Photo Library

KUCC Visit – I (9 March 2004)

Photo Library

KUCC Visit - I
(Worn Grate)

Photo Library

KUCC Visit – I
(Worn shell lifter)

Milestones and Status

Major Milestones Planned to Date/Status

Planned Milestones	***Scheduled***	***Completed***
DESIGN OF PILOT MILL	11/03	50%
BUILD & INSTALL PILOT MILL	02/04	
INSTRUMENT CALIBRATION	05/04	
DRY LOAD TESTING	09/04	
TEST WITH SLURRY (KUCC/CORTEZ)	09/04	
PLANT MILL SURVEY (CORTEZ)	02/05	50%
PLANT MILL SURVEY (KUCC)	05/05	20%
DATA ANALYSIS AND MODELING (CORTEZ)	07/05	50%
DATA ANALYSIS AND MODELING (KUCC)	07/05	10%

Milestones and Status

Key Decision Points Remaining

Decision Point	Scheduled Date	Go/no go
Build pilot SAG mill (grate, pulp and shell lifter)	09/04	
Tests with water and limestone slurry	02/05	
Tests with plant configuration	05/05	

Key Accomplishments

- Pilot Mill Design: Further discussion on pilot mill design with Sami Hindstrom and Travis Orser of Outokumpu Technology Inc. Finalized pilot mill design.

- Paper Presentation: Two paper are presented at SME 2004, and MPD Colorado 2004. One Workshop on ball mill, SAG mill, crushing at Duluth, Minnesota.

- Plant Visits: Two visits to Cortez Gold Mines (CGM) for SAG mill survey and data collection. One visit to Kennecott Utah Copper Corporation (KUCC) for data collection.

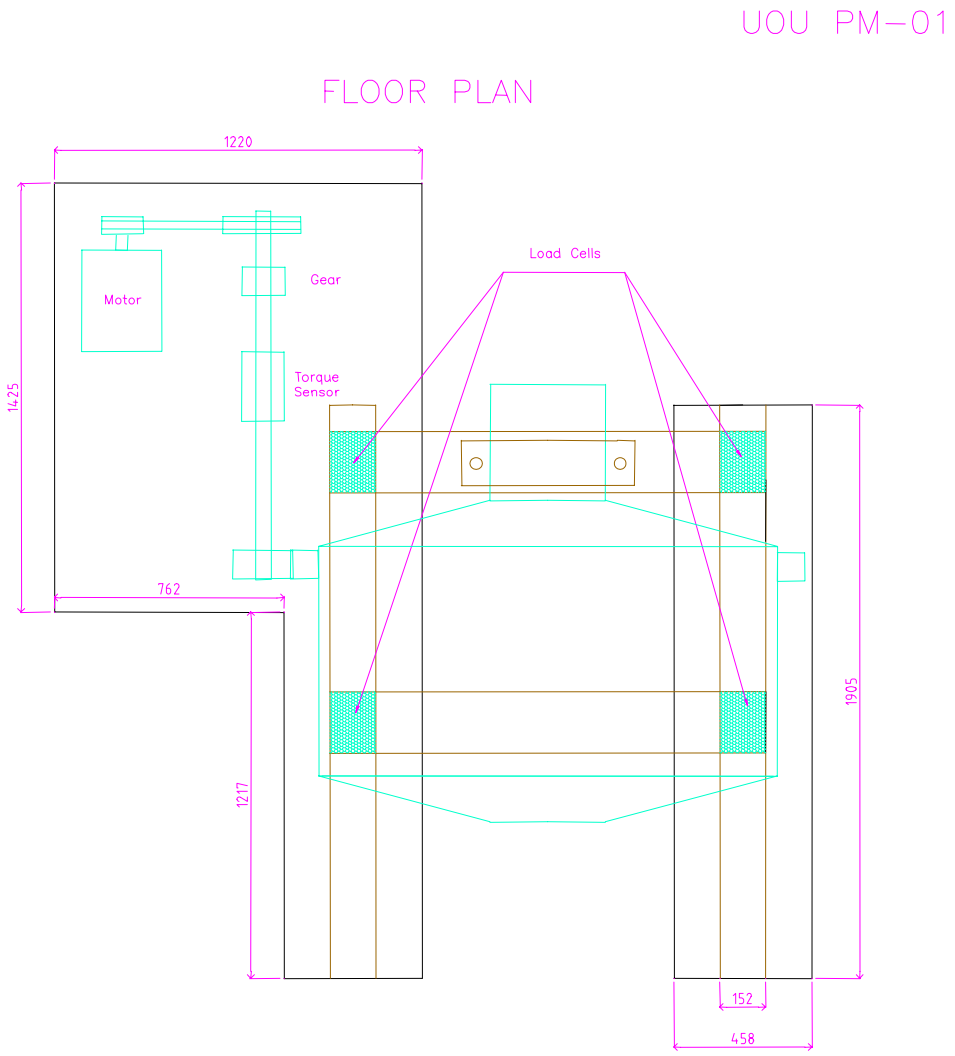
Key Accomplishments – Pilot Mill Design

- Further discussion on pilot mill design with Sami Hindstrom and Travis Orser of Outokumpu Technology Inc.
- Finalized the design of the proposed 5 x 2.5 ft (diameter x length) pilot SAG mill.
- Individual parts are being procured.

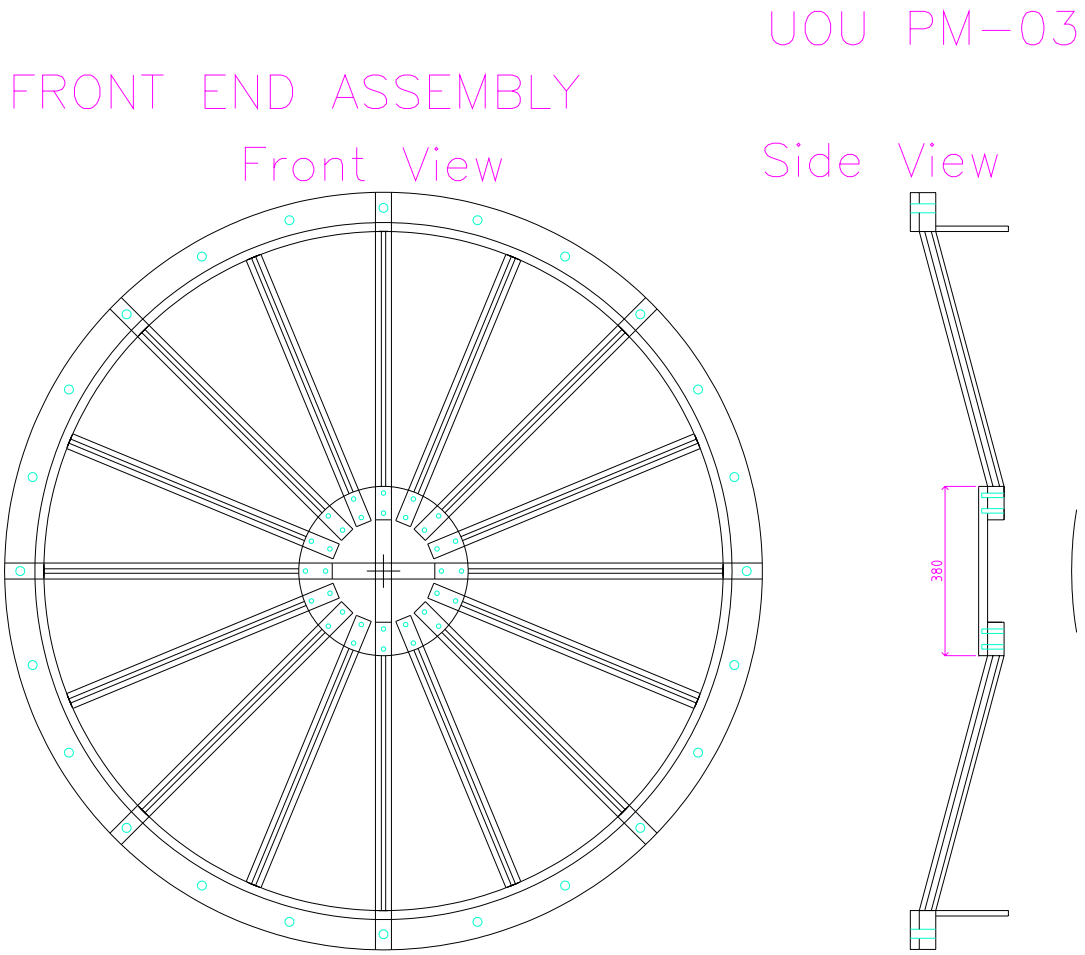
Key items in the design:

- Shell lifter design
- Discharge grate design - open area and position of slots
- Discharge pulp lifter design - radial and curved
- Variable speed drive and motor

Pilot Mill Design



Pilot Mill Design



Key Accomplishments – Paper presentation

1. Mining Energy Solutions Conference organized by DOE at Elko, Nevada, 26-28 August 2003 on "Increasing Energy Efficiency of SAG mills" Sanjeeva Latchireddi and Raj K Rajamani.

2. SME 2004, Denver, 23-25 Feb 2004, Denver on "Grate-only discharge system – An effective method for efficient opoeration of AG/SAG mills" S. Latchireddi, R.K. Rajamani and Travis Orser.

3. Workshop on ball mill, SAG mill, crushing at Duluth, Minnesota, SME meeting. Iron ore range company participants.

4. Paper will be presented at MPD Colorado 2004 on "SAG mill Optimization via proper design of shell and pulp lifters" by S.Latchireddi and R.K. Rajamani

Key Accomplishments – Plant Visits

Cortez Gold Mines visit – I & II

- Made two crash stops of 26ft x 12ft SAG mill
- Collected data on instantaneous charge and slurry hold-up in the mill. Collected operating data for one week prior to the crash stop.
- Conducted grind out of the mill and measured internal shell, grate and pulp lifter dimensions.
- Measured the actual ball charge level in the mill.
- Energy efficiency analysis completed

Kennecott (KUCC) visit – I

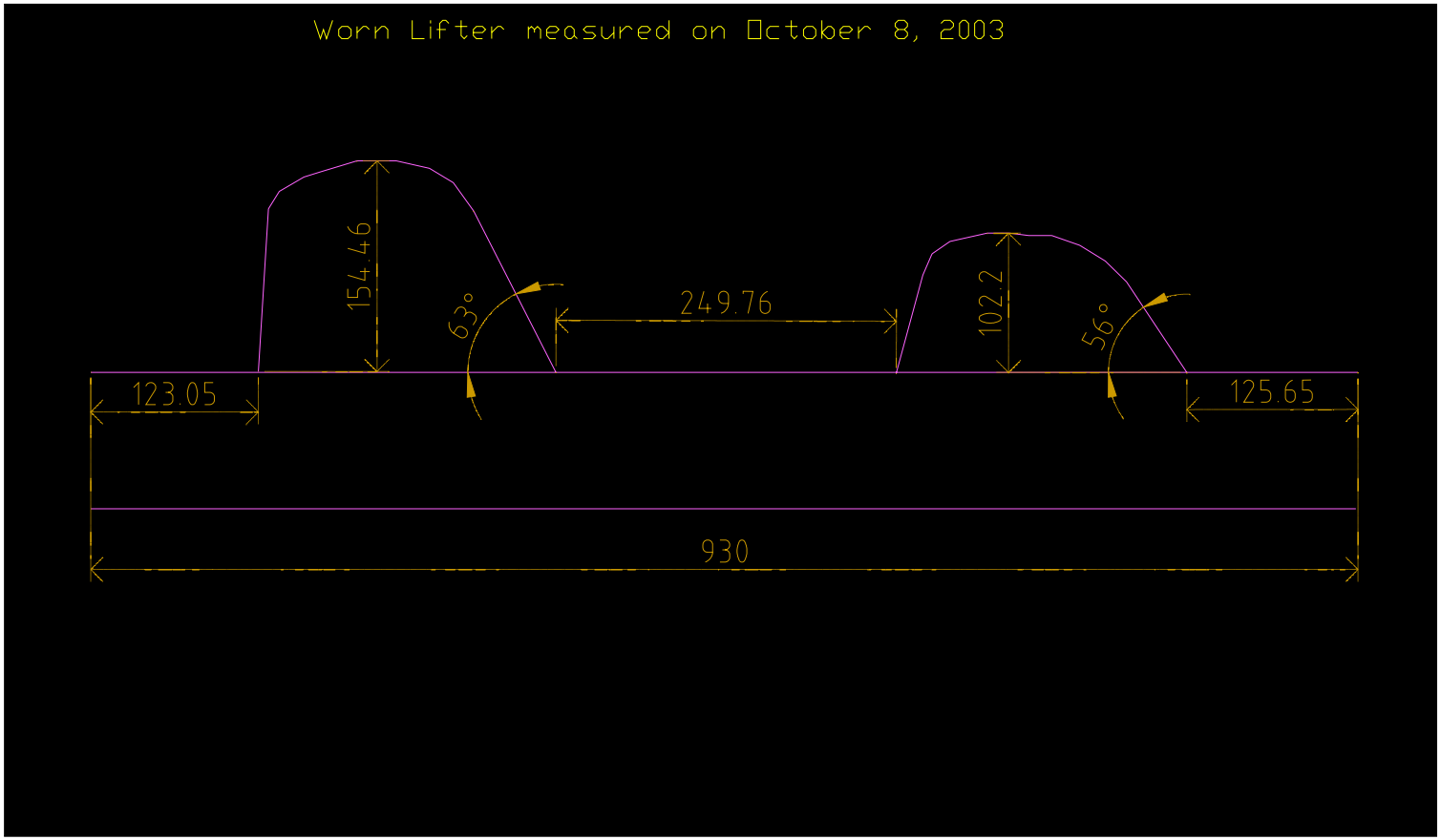
- Examined and took measurements of the worn shell lifters, grate and pulp lifters.
- Estimated metal loss of liners.

Good News!

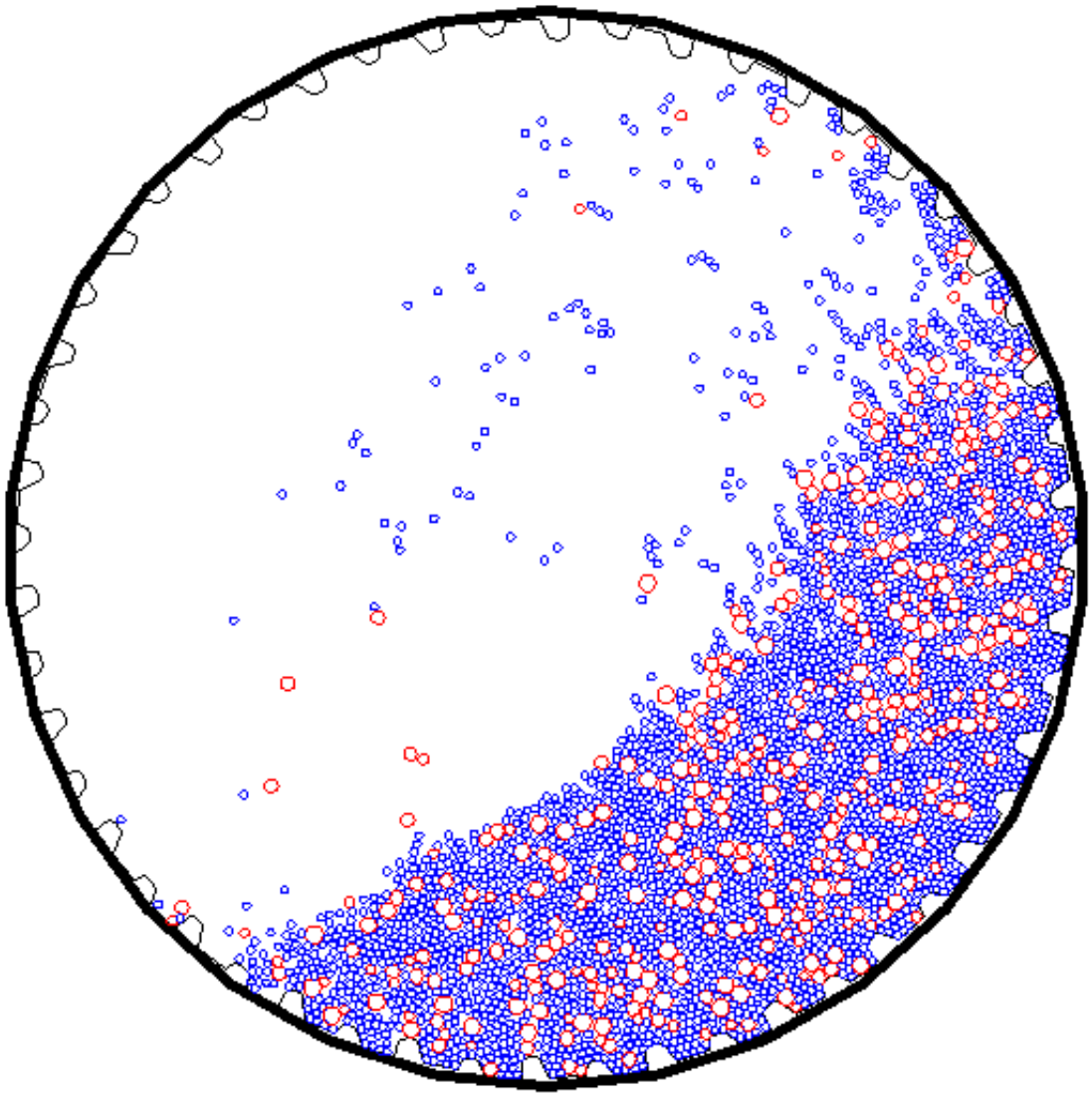
Weir Rubber Engineering, Salt Lake City, Utah joined as cost share project partner

Outokumpu Technology Inc., Centennial, Colorado has joined as cost share project partner.

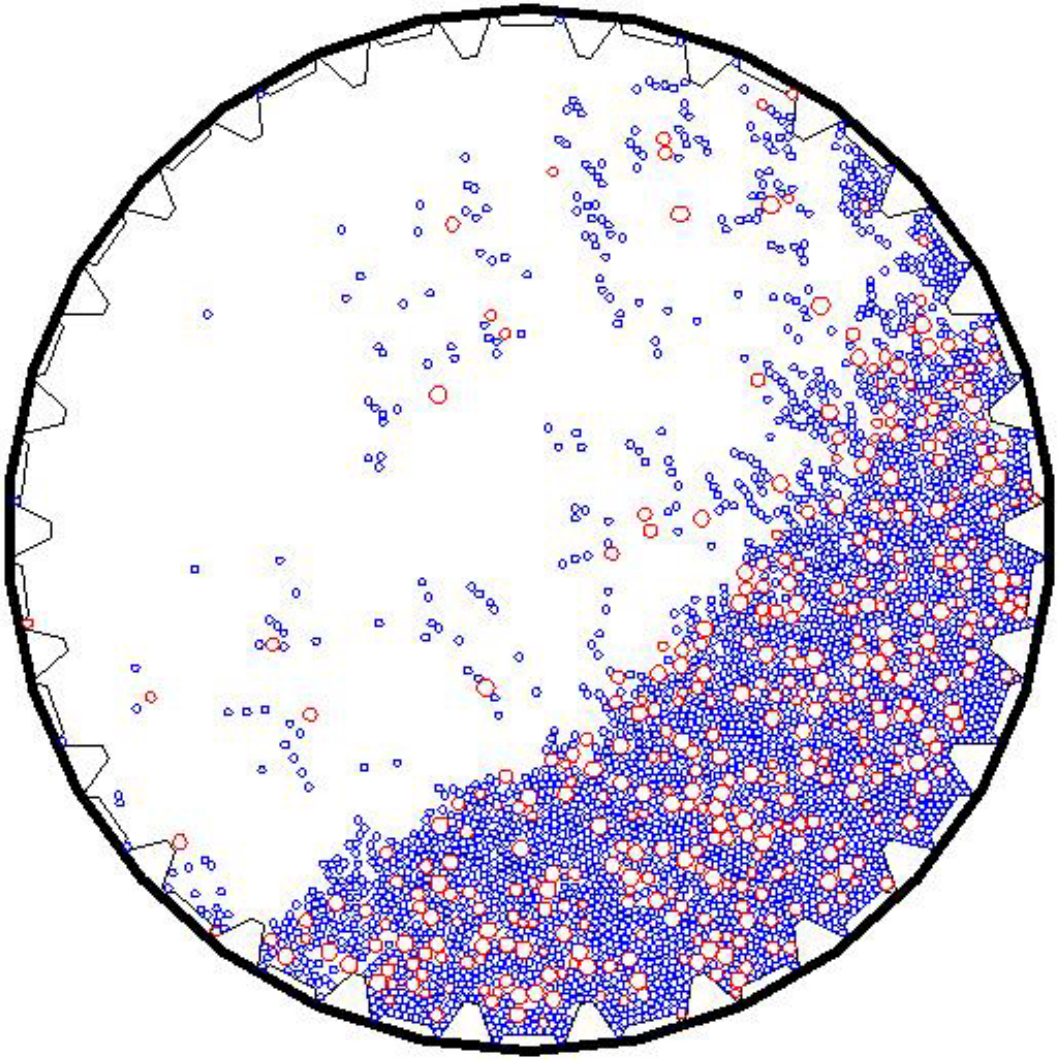
CGM visit - I : Worn lifter measured on 8 October 2003



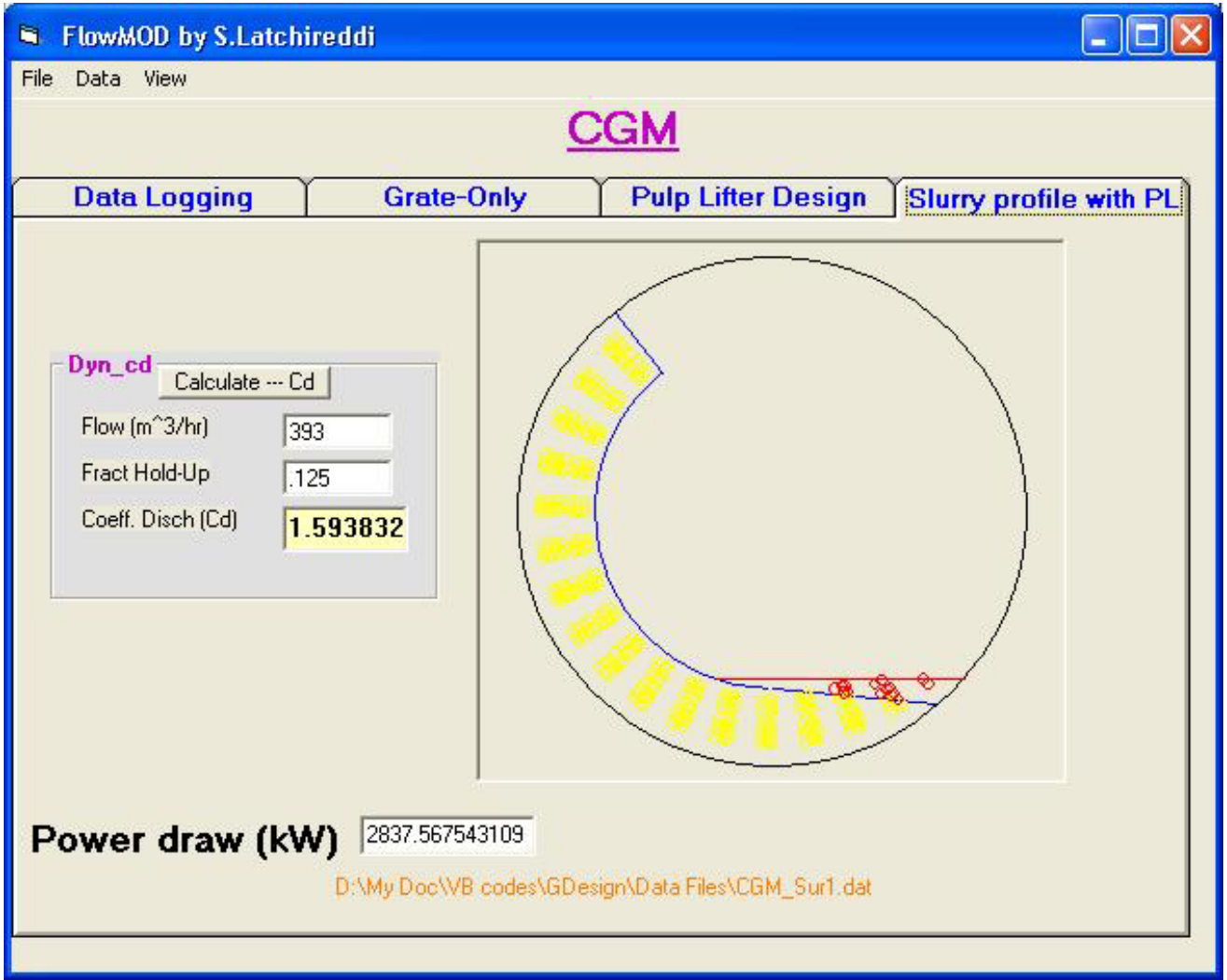
CGM visit – I: Millsoft simulation with worn lifter



CGM visit - I : Proposed U of U design UOU 001

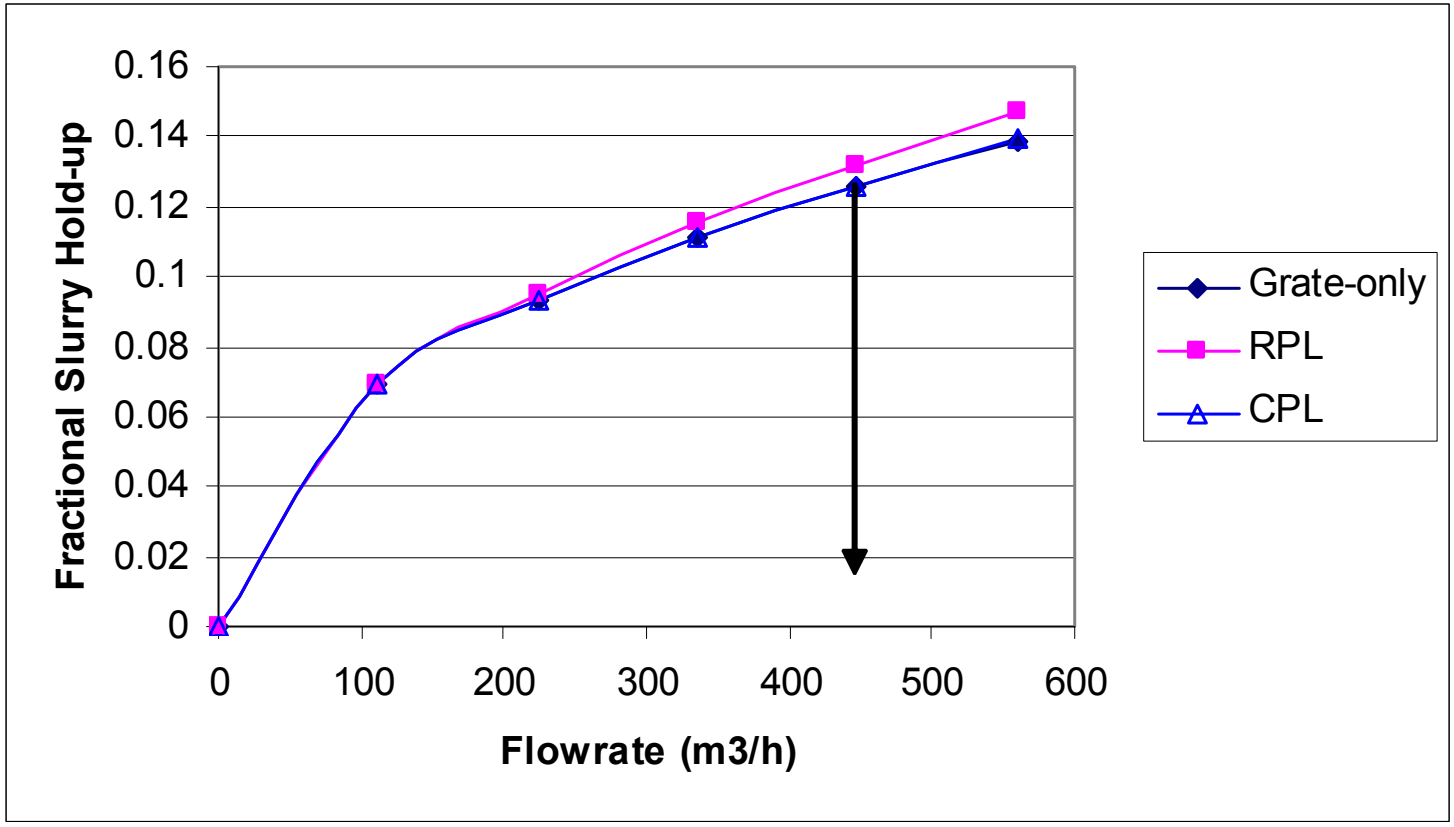


CGM visit – I: FlowMOD Slurry flow Simulation



CGM visit – I: Slurry flow Performance

(after moving the slots by 3 inches back and increasing OA to 9%)



CGM visit – I: Conclusions

1. The mine site is currently changing to new shell lifter design as a result of U of U Millsoft analysis
2. If the current grate slots are pushed 3-4 inches back and the open area increased by drilling 4-6 extra slots per section, the mill capacity is expected to increase by 50-60 m3/h (about 50-75 tph)

CGM visit - II : Crash stop observations (3 march 2004)

- Slurry level of 12 inches above the load (this measurement was taken using UofU fish hook instrument).
- Severe packing between the lifters.

CGM visit – II: packing and slurry pool

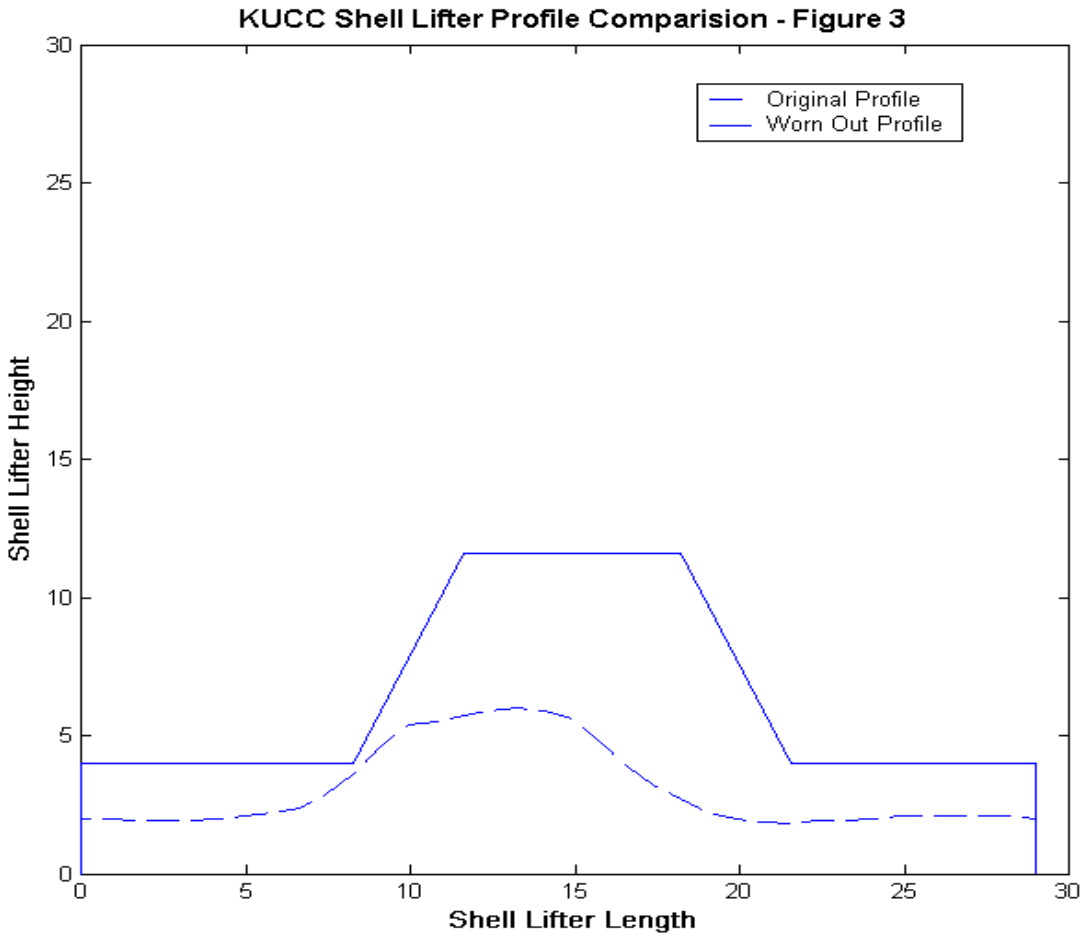
CGM visit - II : Conclusions

- Packing between the lifters is observed as expected with the 17 degree lifters. The proposed UOU 001 shell lifters will overcome this problem.

- A 12 inch deep slurry pool is observed on top of the rock and ball charge. The presence of slurry pool indicates the inefficiency of pulp lifters when the mill load drops due to change in ore characteristics.

- The analysis of the data is in progress.

KUCC visit - I : New and worn lifters on 9 March 2004



KUCC visit - I : Shell lifters worn mass estimation

Parameter	Brand New Lifters	Worn Lifters
Number of Lifters	**88**	**88**
Cross Sectional Area of Lifter (sqr in)	**190**	**102.2**
Length of Each Lifter (in)	**85**	**85**
Density of Steel (kg/m3)	**7800**	**7800**
Mass of Each Lifter (Kgs)	**2,064.17**	**1,110.31**
Volume of Each Lifter (m3)	**0.2646511**	**0.1423544**
Total mass of Shell Lifter (kgs)	**181,647.77**	**97,707.37**
Total Volume of Shell Lifter (m3)	**23.289**	**12.527**
Mass consumption due to wear (kgs)	83,486.80(46.21%)	

KUCC visit - I : Discharge end lifters worn mass estimation

Parameter	Brand New	Worn
Cross Sectional Area of Lifter (sqr in)	**55.40**	**20.40**
Total Volume of Steel (m^3)	**11.530**	**9.214**
Density of Steel (kg/m3)	**7800**	**7800**
Total Mass of Steel (kgs)	**89,930.49**	**71,870.62**
Mass consumption due to wear (kgs)	18,060.13(20.08%)	

KUCC visit - I : Feed end lifters worn mass estimation

Parameter	Brand New	Worn
Cross Sectional Area of Lifter (sqr in)	**82.0**	**60.0**
Total Volume of Steel (m^3)	**11.611**	**9.706**
Density of Steel (kg/m3)	**7800**	**7800**
Total Mass of Steel (kgs)	**90,564.57**	**75,705.60**
Mass consumption due to wear (kgs)	14,858.97(16.4%)	

Commercialization Outlook

- LICENSING AGREEMENT POSSIBLE AS NEW DESIGNS ARE MADE
- FIRST CUSTOMERS LIKELY TO BE HOST SITES
- TECHNOLOGY WILL BE AGGRESSIVELY MARKETED THROUGH EXISTING INDUSTRY CONTACTS AND TOURS

Total Ore Process Integration And Management

- **Principal Investigators:** Dr. Richard Gertsch and Dr. Leslie Gertsch, UMR
- **NETL Project Manager:** Mike Mosser
- **Cost Share Partners:**

  US Steel – Minntac Mine, Cleveland Cliffs – Hibtac Mine; University of Missouri-Rolla; Wipware; Eloranta & Assoc.; Mount Sopris Instruments; Thunderbird Pacific; Viking Explosives; Metso Minerals, Mintec Inc.
- **Total Project Cost:** $3,004,638
  - DOE Share: $622,639
  - Participant Share: $2,381,999
- **Project Period:** 36 months
- **Project Start Date:** Aug 2003

The Project

OBJECTIVE:

Lower overall costs – particularly energy costs – by optimizing the entire mining and processing system.

STRATEGY:

1. Build a baseline of current practices and knowledge, THEN
2. Make single changes to the process and measure the effects, one-by-one.

The TOPIM Process

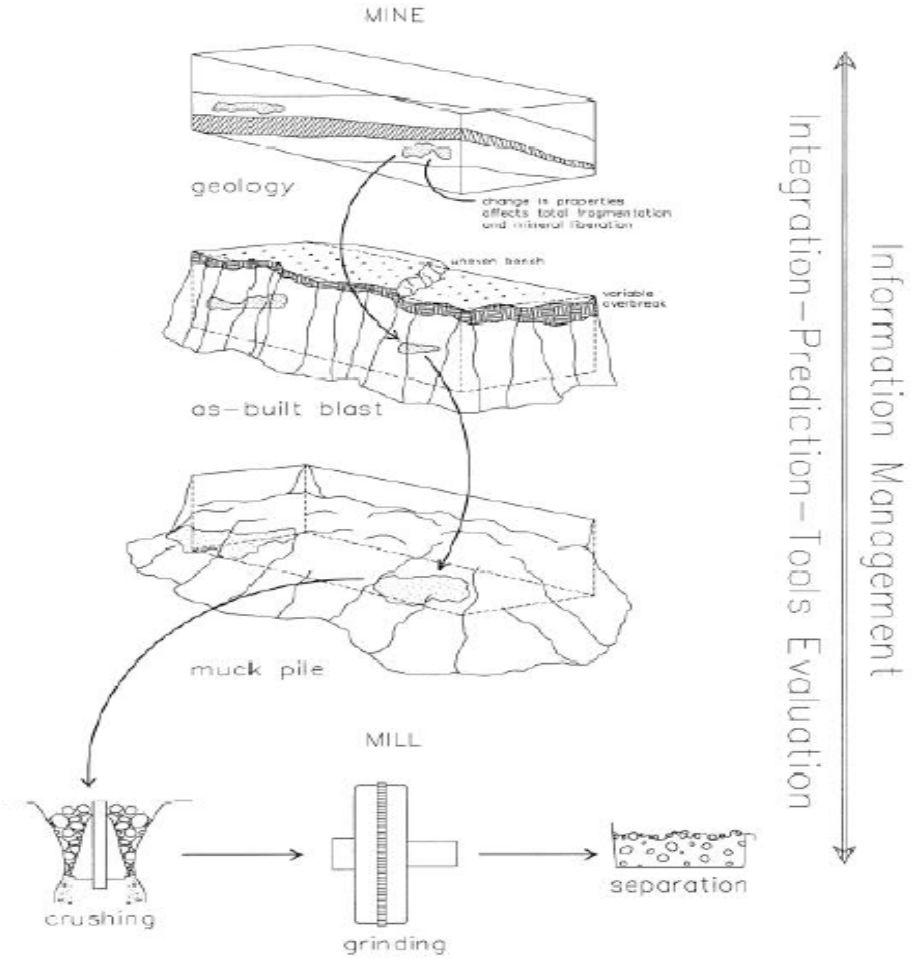


Figure 1. Schematic diagram of the the TOPIM System concept. TOPIM will provide mine and mill personnel with the means to identify areas in the geology that affect downstream outcomes, in time to react before the ore reaches the sensitive processing step.

TOPIM Interrelationships

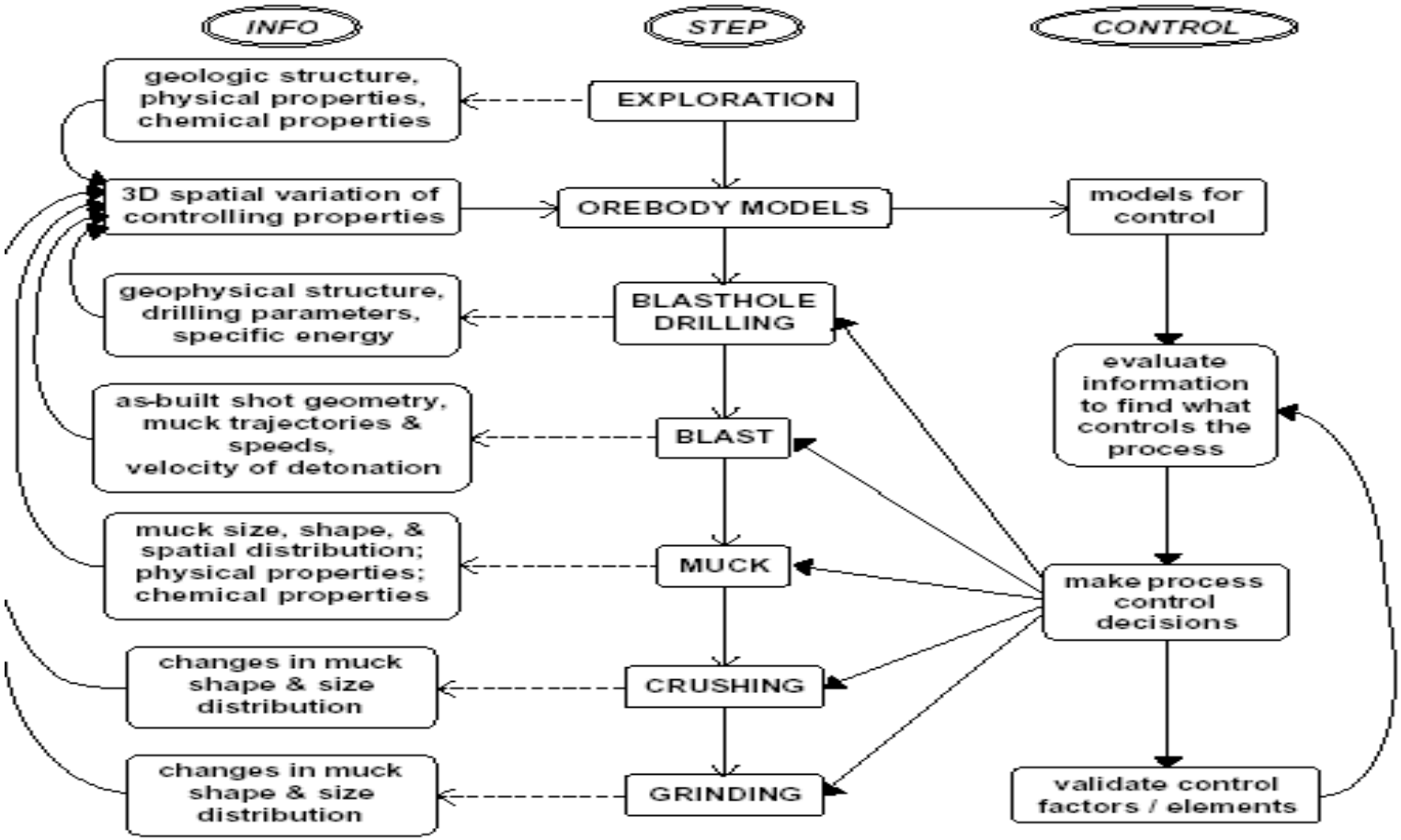


Figure 2. Schematic diagram of the approach planned for development of the TOPIM System. The central column (STEP) corresponds to Task 1, the left column (INFO) to Task 2, and the right column (CONTROL) to Task 3.

Milestones and Status

Milestone	***Schedule***	***Status***
OVERALL PROCESS BASELINING & EVALUATION	**00 – 18 months**	***UNDERWAY***
FIELD TESTS & MEASUREMENTS	**03 – 30 months**	***UNDERWAY***
TOPIM SYSTEM DESIGN **Measure Process Changes** **Control Process Changes**	**18 – 33 months**	
BUSINESS DEVELOPMENT & TECH TRANSFER	**24 – 36 months**	

Key Accomplishments

Data Mining and Analysis

- Hypothesis testing of second Minntac Mine ore segregation test results, including crushing energy.
- Orebody structure, chemistry, mineralogy, and texture of Minntac and Hibtac Mines.

Segregation Test

- High vs. low-powder factor test performed at Hibtac Mine.

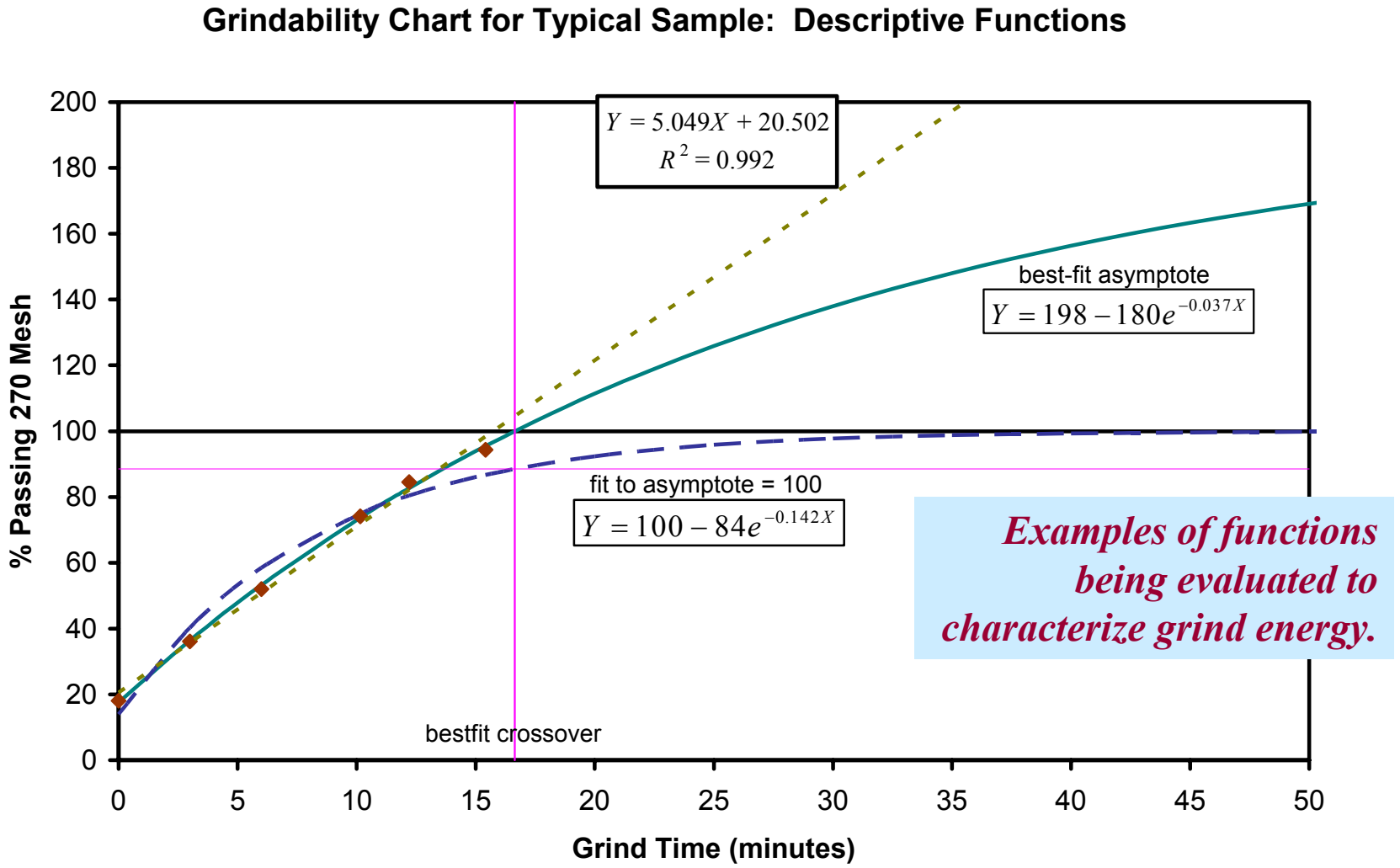
Baselining at Minntac and Hibtac Mines

- Ore grinding energy and liberation.
- Blasthole drill performance.

Orebody Modeling at Minntac Mine

- Layer & level maps, and cross-sections of nonstandard parameters.

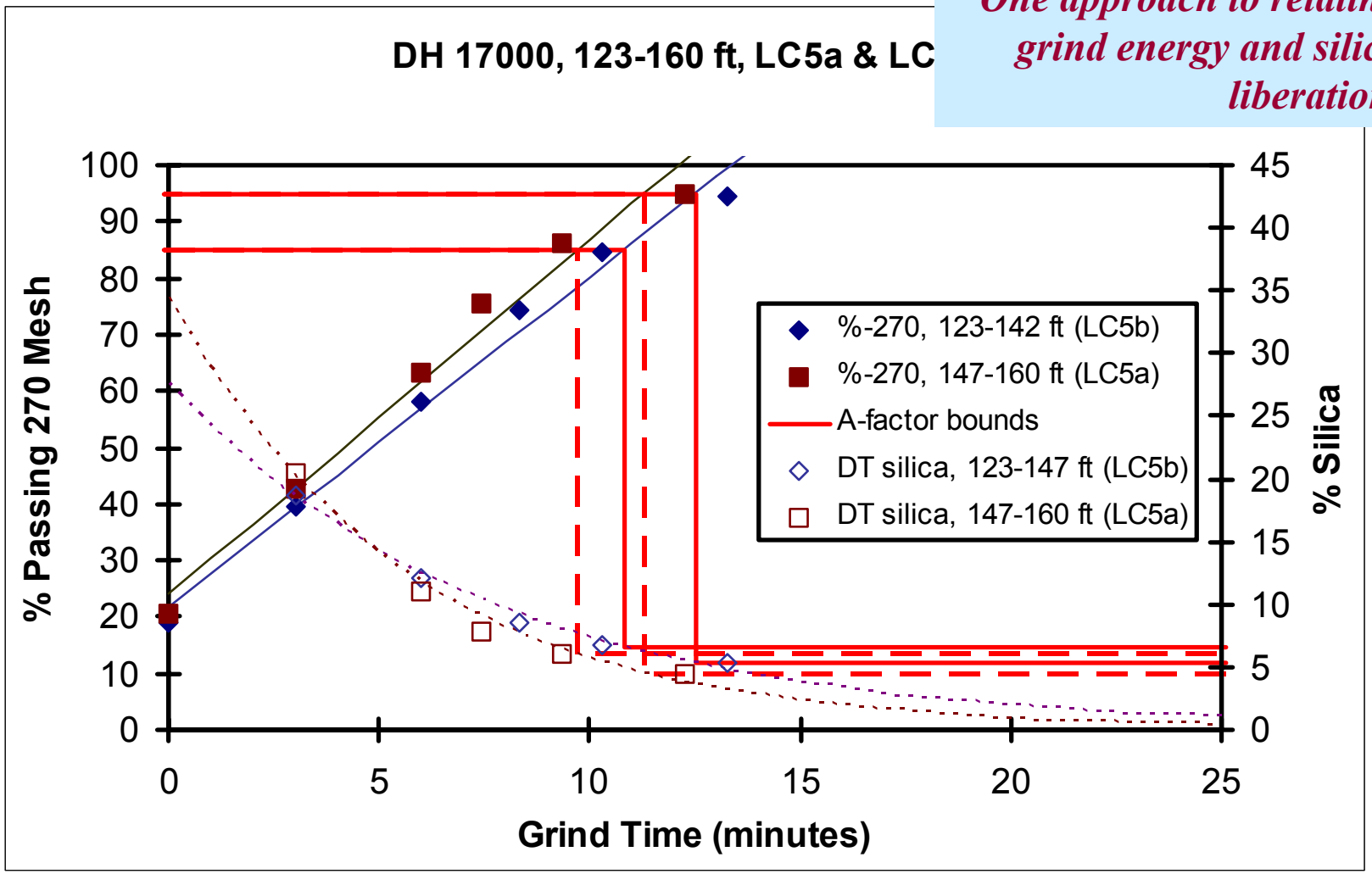
Preliminary Results



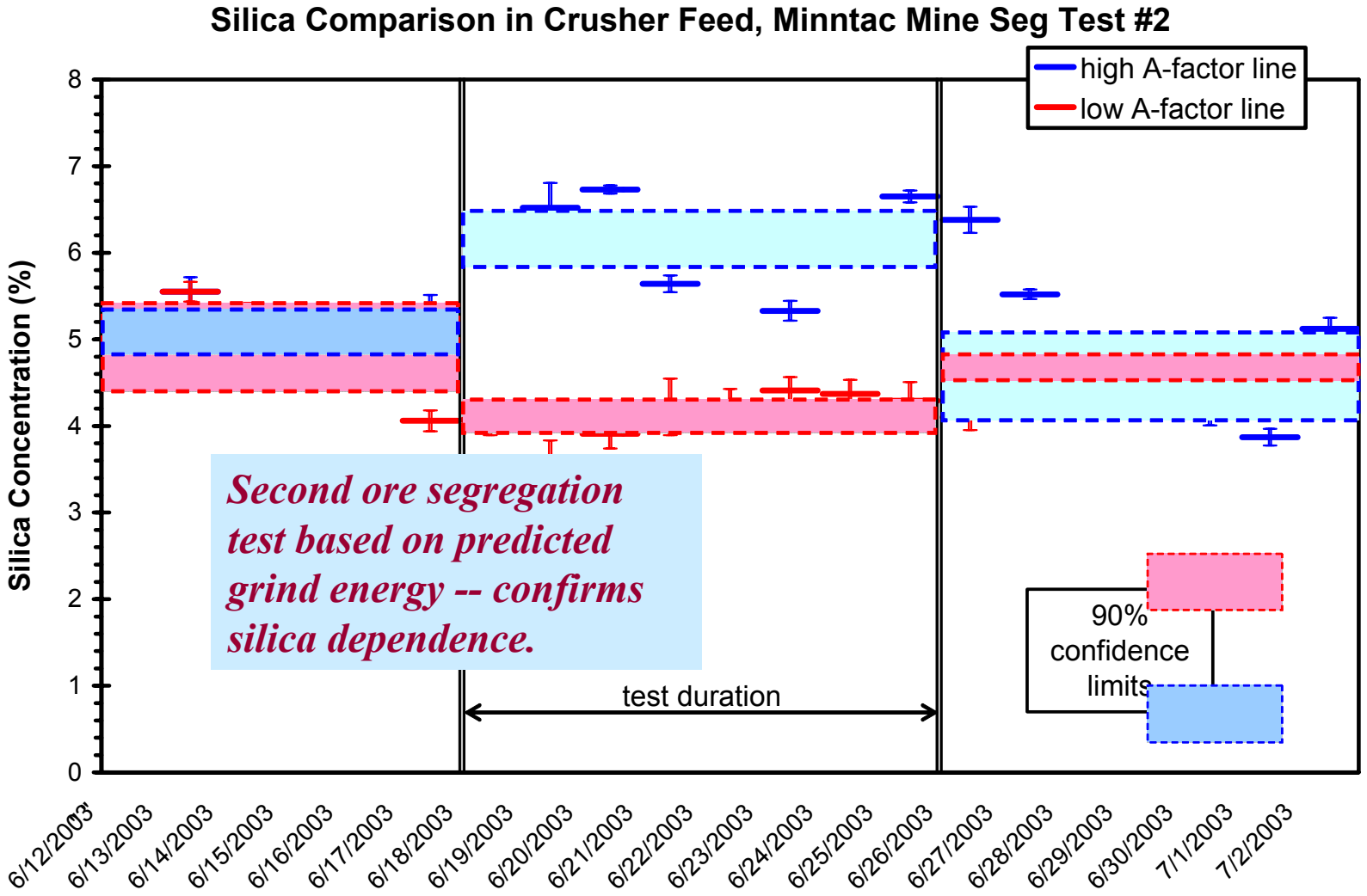
Examples of functions being evaluated to characterize grind energy.

Preliminary Results

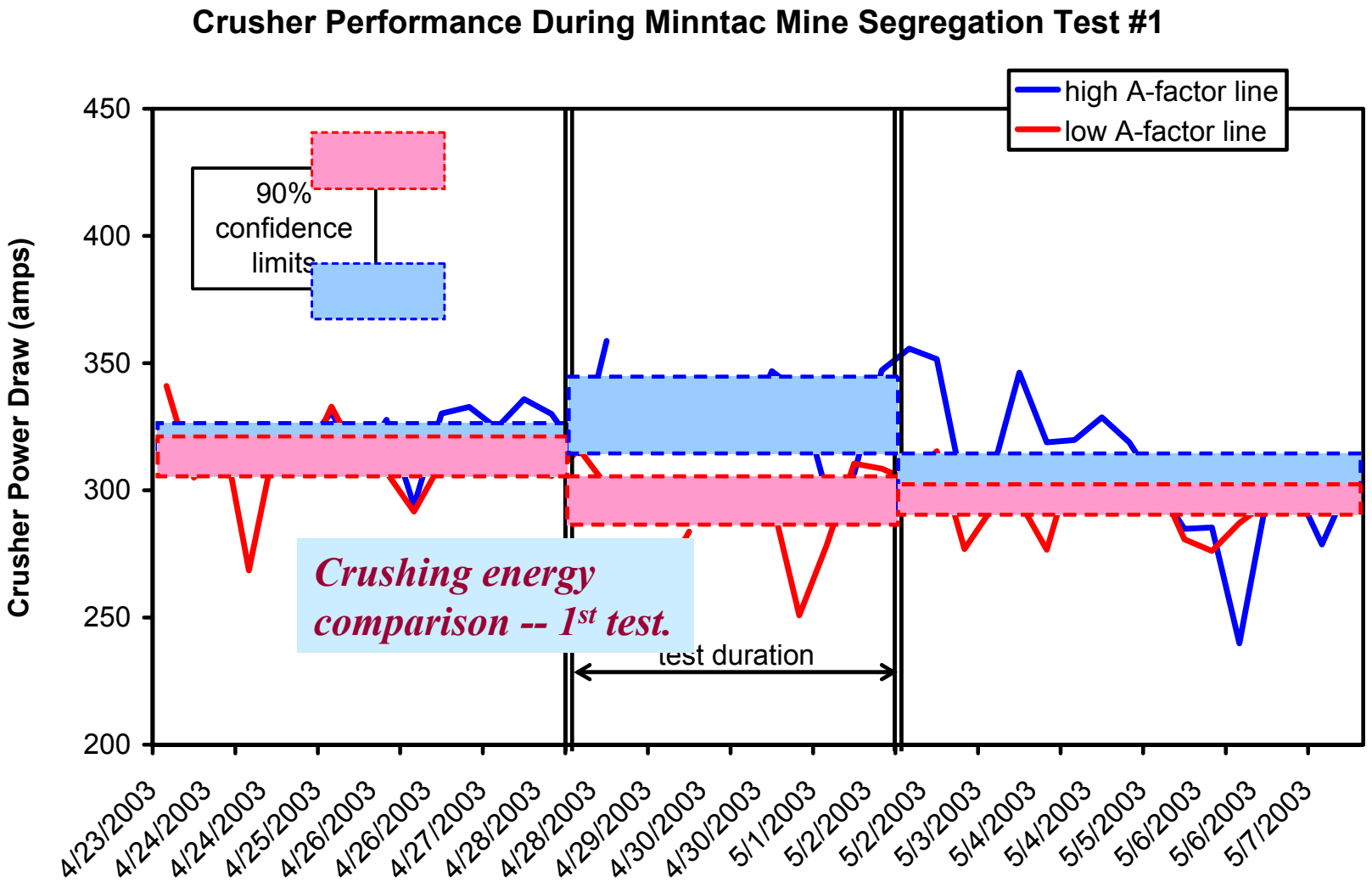
One approach to relating grind energy and silica liberation.



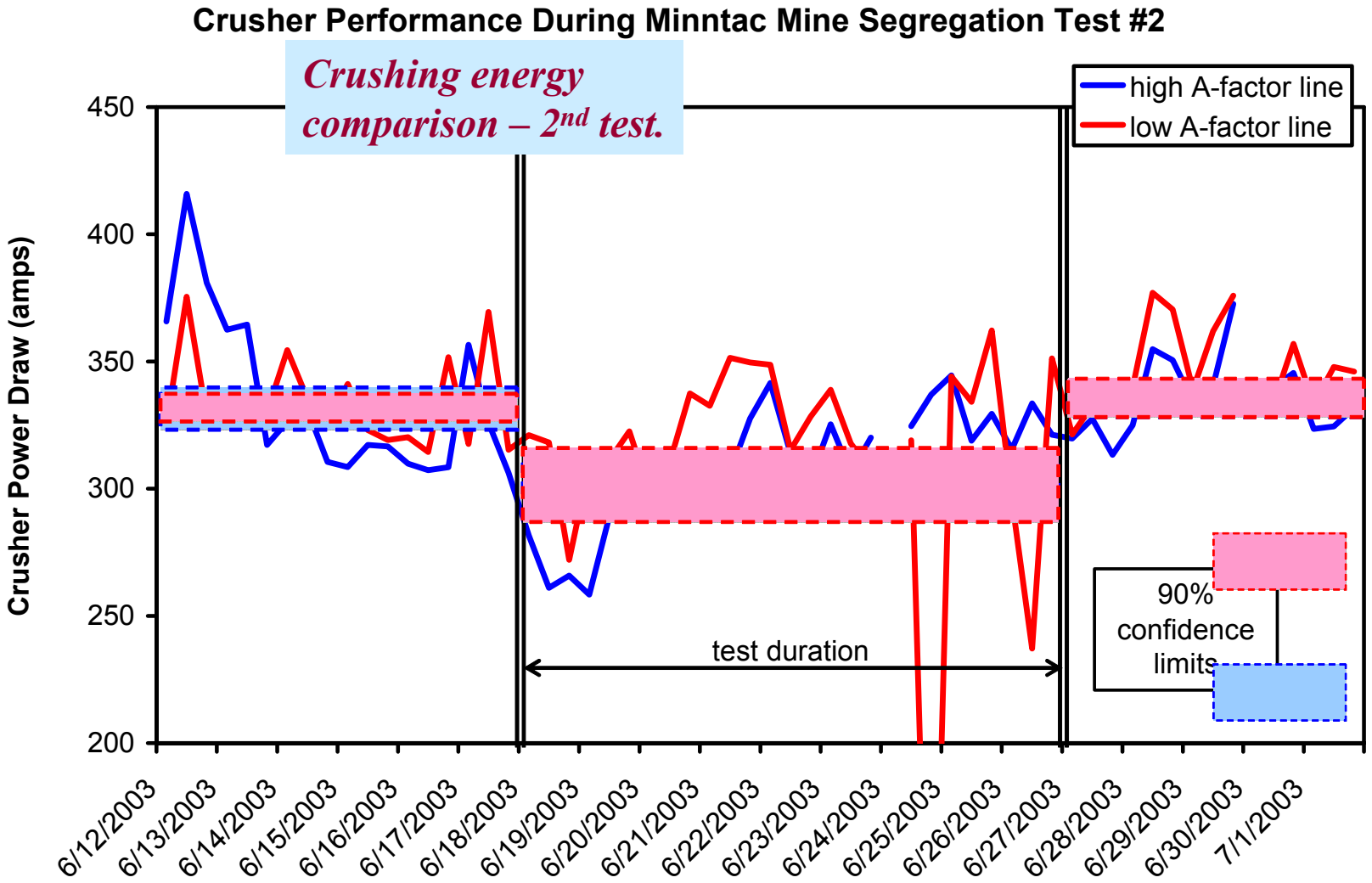
Preliminary Results



Preliminary Results



Preliminary Results



Tasks for Next Quarter

Data Mining and Analysis

- Hypothesis testing of Hibtac Mine ore segregation tests.
- More powerful analyses of Minntac Mine ore segregation tests.
- Bring fragment size analysis system online at Hibtac Mine.

Segregation Tests

- Design and schedule ore segregation tests for Minntac and Hibtac Mines.

Continue Baselining at Minntac and Hibtac Mines

- Relate data between the two mines.

Orebody Modeling

- Predict Minntac Mine concentrator performance.
- Add nonstandard parameters to Hibtac Mine model.

Commercialization

NEW USES FOR EXISTING PRODUCTS

- Use size analysis imaging system to optimize and control AG mill feed.
- Use drill performance monitoring to predict and control comminution energy and liberation.
- Use drill performance monitoring to increase concentrator efficiency.
- Use blasthole geophysics to predict comminution and concentrator performance.

LONG RANGE PRODUCTS

- New process control methods and protocol.
- First customers – host sites.
- TOPIM system disseminated through publications and industry contacts.

Project Recognition

- **Inquiries**
  - From organizers of a South American symposium on energy reduction in mining and milling.
  - February, 2004

- **SME 2004 Duluth Section Meeting**
  - A complete technical session to increase industry awareness of TOPIM.
  - April 13-14, 2004