ADMINISTRATIVE INFORMATION

1. **Project Name:** Multifunctional Metallic and Refractory Materials for Energy Efficient Handling of Molten Metals

2. **Lead Organization:**

West Virginia University
Department of Mechanical and Aerospace Engineering
P.O. Box 6106
Morgantown, WV 26506-6106

Oak Ridge National Laboratory
Material Science and Technology Division
One Bethel Valley Road
Oak Ridge, TN 37831-6083

University of Missouri-Rolla
Department of Ceramic Engineering
P.O. Box 314
Rolla, MO 65402

3. **Principal Investigator:**

Ever J. Barbero, Professor and Chairman
Department of Mechanical and Aerospace Engineering
West Virginia University
(304) 293-3111 x2335
(304) 293-6689 (fax)
ebarbero@wvu.edu

4. **Project Partners:**

ILZRO
Frank Goodwin
fgoodwin@ilzro.org,
(919) 361-4647 x 3018

Energy Industries of Ohio
Larry Boyd
boyd@energyohio.com,
(216) 662-7044

SECAT, INC.
Subodh Das
skdas@secat.net
(859) 514-4989

WV Steel Futures, Inc.
George Psaros
(304) 723-4278

The Techs
James Anderson
janderson@thetechs.com
(412) 464-5000

Allied Minerals
Dana Goski
dgg@alliedmin.com
(614) 876-0244

AK Steel
Paul Janavicius
Paul_Janavicius@aksteel.com
(513) 425-2670

Teckcominco
Paul Kolisnyk
Paul.kolisnyk@teckcominco.com
(905) 822-2022 x234

Duraloy Technologies
Roman Pankiw
techmgr@duraloy.com
(724) 887-5100

Special Metals
Ram Iyengar
riyengar@smcwv.com
(304) 723-3701

Praxair Technologies
Michael Brennan
Michael_Brennan@praxair.com
(724) 598-1344

Metaullics Systems
Mark Bright
mabright@metaullics.com
(440) 349-8826

Monofrax Refractory
Amul Gupta
Amul_Gupta@cp.vesuvius.com
(716) 483-7270

MORCO Refractory
Mike Heying
mikeh@morco-inc.com
(636) 479-7770

Pechiney Rolled Products
Scott Goodrich
Scott.goodrich@pechiney.com
(304) 273-6707

Weirton Steel
Howard Snyder
howard.snyder@weirton.com
(304) 797-4999

Magneco/Metrel
Michael Anderson
mike@magneco-metrel.com
(630) 543-6660

Blasch
David Larsen
dlarsen@blaschceramics.com
(518) 436-1263

Sturm Rapid Response
Scottie Workman
scottie.workman@sulzerpumps.com
(304) 733-3229

Thermal Ceramics
Jason Street
jstreet@thermalceramics.com
(706) 796-4200

Unifrax
Gary Deren
gderen@unifrax.com
(716) 278-3821

Vesuvius McDaniel
Edward Dean
Ed.Dean@vesuvius.com
(724) 843-8300 x215

Emhart Glass
Steve Herrington
steve.herrington@emhartglass.com
(573) 437-2132 x220

Deloro Stellite
Jim Wu
jwu@stellite.com
(314) 983-0266 x15

Wheatland Tube Co.
J.A. Gruber
Jack.gruber@wheatland.com
(724) 346-7255

Kyanite Mining
Jesse Brown
jessebrown@kyanite.com
(434) 983-2085

California Steel Corp
Mike Syrko
msyrko@californiasteel.com
(909) 350-6300

5. **Date Project Initiated:** March 1, 2004

6. **Expected Completion Date:** February 28, 2007 (November 28, 2007 with anticipated no cost extension)

PROJECT RATIONALE AND STRATEGY

7. **Project Objective:**

The project goal is to extend the lifetime of molten metal containment and submerged hardware materials by an order of magnitude, while also improving the thermal efficiency of refractory materials resulting in estimated energy savings of approximately 1.79 trillion BTU/year by 2020.

8. **Technical Barrier(s) Being Addressed:**

Corrosion, wear, and abrasion of hardware and refractory used in the aluminum, steel, and metal casting industries, cause frequent production shutdowns with large energy consumption during shutdowns. The barrier to industrial energy efficiency addressed by this project is the increased *durability of submerged hardware and refractory lining*. The technical challenges are (1) dynamic erosion/corrosion; (2) dross buildup; and (3) wetting leading to erosion/corrosion.

9. **Project Pathway:**

The pathway being used to address the barrier to industrial energy efficiency consists of (1) identification of physicochemical mechanisms of corrosion, wear, and abrasion; (2) development of new generation materials, coatings, and deposition processes with potential 10X improvement in performance; (3) lab-scale evaluation of performance, durability, and thermal conductivity of newly developed materials; (4) in-plant evaluation/demonstration of components fabricated with newly developed materials and processes; and (5) technology commercialization.

10. **Critical Metrics:**

- Demonstrating 10X life increase of Galvanizing hardware (from 4 days current to 40 days target)
- Demonstrating 2X life increase of refractory used in Al production (from 2 years current to 4 years target)
- Demonstrating energy savings of 1.79 trillion BTU/year from the technologies developed by this project.

PROJECT PLANS AND PROGRESS

11. **Past Accomplishments:**

- **Industrial survey on pot hardware materials in galvanizing industry and refractories used in aluminum melting industry, completed**. Provides baseline of current industrial energy consumption.
- **Relationship between dynamic corrosion and dross formation on roll surfaces has been identified**. Laboratory scale corrosion research on current and newly developed materials has led to an understanding of the dynamic corrosion and dross formation that occurs on steel galvanizing rolls. See DoE ITP E-bulletin http://www.eere.energy.gov/industry/imf/pdfs/corrosionresistant.pdf (April 2006)
- **New Corrosion and Dross Resistant Overlay has been Developed and Evaluated in Industrial Setting:** A new corrosion, wear, and dross-buildup resistant weld overlay with greater than 5X lifetime improvements over current stainless steel has been developed and validated

through the exposure of weld-overlay material samples for over 81-days in an industrial setting. Materials are functioning well with little evidence of corrosion**.**

- **Industrial Component Testing of New Overlay is Underway:** One galvanizing partner has donated a stabilizer roll for the trial. The roll has been machined by a component supplier and it has been shipped to ORNL for weld overlay. Once the overlay is finished, it will be shipped back to the galvanizing partner for in-plant production trial.
- **New Scraper Blade System in GL Production Has Been Designed**: A new scrapper-blade system that is interchangeable with the existing scrapper part in the CGL line has been designed. The new scrapper-blade system incorporates a mechanism for interchangeable inserts of newly developed hard materials.
- **New Refractory Materials Are Being Developed:** In-kind partners are working in conjunction with UMR & ORNL to develop new refractory compositions. Three new compositions are being pursued based on improved raw materials, new material system alternatives, and novel processing techniques. Sessile drop testing at ORNL, along with lab-scale corrosion testing at UMR and ORNL have confirmed the advantage of these materials in comparison with current ones.
- **New Anti-Wetting Agents have been Investigated**: Materials which thermodynamically show promise as anti-wetting agents at higher temperature have been identified and acquired. High purity samples have been prepared for sessile drop testing to determine the anti-wetting ability of new compositions versus conventional anti-wetting agents.
- **A New Thermal Conductivity Technique Was Developed at ORNL for the Measurement of Thermal Diffusivity of Large Refractory Samples:** Installation was completed of the new device into the existing infra-red lamp facility at ORNL and thermal diffusivity measurements were made on full-size refractory samples with known conductivities to validate the method. Testing will continue on samples with both known and unknown conductivity values in support of new material development and evaluation.
- **Analysis of Potential Energy Savings Due To Improvements in Refractory Materials Were Performed:** These analyses were performed using the DOE software tools PHAST and 3E-Plus, along with basic heat transfer theory. Analyses assumed a hypothetical reverberatory furnace in an Aluminum plant with improvements made in wall losses through better insulation, improvements in net and gross heat required by the furnace, energy used by the furnace, and thermal efficiency. Thermal conductivity measurement on new materials using the newly developed large-sample IR-based technique will be used to make further energy predictions.
- **Galvanizing Energy Profiler and Decision Support System (GEPDSS) Was Developed**: a New Decision Support System identifies opportunities for energy savings in steel coating lines based on improvements in pot hardware characteristics and energy consuming equipment on the galvanizing lines. A multilayered engineering-based energy evaluation model was developed. This model quantitatively determines energy and productivity benefits resulting from the implementation of new pot hardware materials in galvanizing lines. The model has been validated and demonstrated to report estimated galvanizing line energy consumption accurate within 5% of actual energy consumption in several galvanizing lines of industrial partners and accurately estimates in variances in production and energy consumption with respect to changing line equipment characteristics. See DoE ITP E-bulletin http://www.eere.doe.gov/industry/imf/pdfs/multi_func_mats.pdf (July 2006)

12. Future Plans:

Date	Milestone/Deliverable	Lead Partner
12/06	New Refractory Development	UMR & ORNL
03/07	Lab-scale of Metallic Overlay	WVU (Lab), ORNL (in-plant)
03/07	Lab-scale of new refractory	UMR & ORNL (Lab), EIO (in-plant)

Date	Milestone/Deliverable	Lead Partner
09/07	Industrial in-plant Evaluation of Metallic Overlay during actual production	WVU (Coordinating & post mortem analysis); ORNL (coating), Duraloy (roll machining), Steel companies (testing)
09/07	Industrial in-plant Evaluation of New Refractory during actual production	EIO and SECAT (two independent evaluations)
11/07	Final Report	WVU

13. **Project Changes:**

The project objectives have been more tightly focused to overcome the main barriers and to demonstrate the technology on a set of industrial process that are representative and cross-cutting among the aluminum, steel, and metal casting industries.

14. **Commercialization Potential, Plans, and Activities:** (Describe the end-use application and market potential for the project, and the plans, progress, and partners for commercial application/adoption, where appropriate; identify the product of the project and how this product will be introduced and disseminated to industry.)

This project represents a technology-pull from industry as opposed to a technology-push from academia. The project team includes all the components required for successful commercialization of the technology developed by the research, including hardware and refractory suppliers, galvanizers and aluminum producers, and industrial organizations. All the partners have been involved from the beginning of the research and it has been decided that at the end of the project, the industrial organizations (SECAT, EIO, and ILZRO) will take the lead on commercialization of the technologies.

15. **Patents, Publications, Presentations:**

1. X. Liu et al., "Progress Report: Minimizing Dross Buildup on Rotating Galvanizing Bath Hardware", ILZRO-GAP 2006, (May 2006), Cleveland, OH
2. X. Liu, C. Irwin, E. Barbero, B. Kang: "Minimizing Dross Buildup on Rotating Galvanizing Bath Hardware", ILZRO-GAP 2005, (October 2005) Lexington, KY
3. X. Liu, E. Barbero, C. Irwin, V. Sikka, J. Hemrick, W. Headrick & F. Goodwin: "Development of Next Generation of Metallic and Refractory Materials for Molten Metals Handling", AISTech 2005 Iron & Steel Technology Conference and Exposition, Charlotte, NC
4. X. Liu et al.: "Progress Report: Minimizing Dross Buildup on Rotating Galvanizing Bath Hardware", ILZRO-GAP 2005, (May 2005), Charlotte, NC
5. E. Barbero, X. Liu et al.: "Current Research on Zinc Pot Hardware and Molten Metal Containment" in Galvanizers Association Annual Meeting 2004, Charleston, SC.
6. J.G. Hemrick: "New Thermal Conductivity Technique Development at ORNL" presented at American Petroleum Institute Meeting in Dallas, TX (May 2006).
7. J.G. Hemrick, V. Sikka, and W. Headrick: "Multifunctional Refractory Materials for Molten Metal Contact Applications" – (Paper UN-GS-7-2005), UNITECR' 05 Meeting in Orlando Florida, November 2005.
8. J.G. Hemrick and E. Loveland: "Technique Development for Large Sample Thermal Conductivity Measurement" – (Paper UN-GS-42-2005), UNITECR' 05 Meeting in Orlando Florida, November 2005.