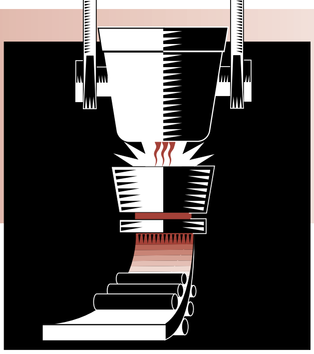

# STEEL

Project Fact Sheet

## Clean Steels: Advancing the State of the Art

### Benefits

- Increased productivity and decreased defects resulting in improved efficiency of hot charging
- Reduced energy consumption
- Estimated annual savings of $10 million when technology is in widespread commercial use

### Applications

Research results will be applicable to inclusion removal in ladle, tundish, and continuous casting mold to increase life of products, such as bearings and bars. It is anticipated that this project would result in significant yield improvements in prime production tonnage.

### Improvements in steel cleanliness will result in increased productivity and improved efficiency while reducing overall energy consumption in the steel industry

Steel cleanliness is the one unifying theme in all steel plants as problems in steel cleanliness can lead to internal rejects or customer dissatisfaction with steel products. Thus, all steel plants are continually attempting to improve their practices to produce more consistent products. In addition to product consistency, it is now clear that fatigue resistance and tool and die life correlate strongly with steel cleanliness. Improvements in steel cleanliness will result in further improvements in steel performance.

The future goal of steelmaking and casting will be to continue to reduce the total oxide inclusion mass in liquid steels and to ensure that the remaining inclusion chemistry and size distribution is closely controlled. The purpose of this project is to determine the potential limiting factors in production of clean steels and to produce on the laboratory scale ultra clean steels beyond that currently available in bulk production. This project will lead to the development of processes or process strategies that will allow cleaner and more consistent steels to be produced. This issue is extremely important in the production of bar grades where fatigue strength is vitally important.

The American Iron and Steel Institute's (AISI) Technology Roadmap Program (TRP) and the Center for Iron and Steelmaking Research at Carnegie Mellon University, in conjunction with the U.S. Department of Energy (DOE), are conducting this three-year project that will lead to a better understanding of the practices and mechanisms responsible for the formation of large inclusions in cast steels. In turn, this will lead to practices that will result in the ability to produce cleaner steels, increase productivity, and minimize product defects. Thus, this work will aid in reducing the overall energy consumption of the steel industry by aiding in increased productivity and decreased defect ratio, both key components in successful hot charging.

#### Clean Steels

**Figure 1.** Direct observation of the agglomeration of TiN inclusions at a slag/stainless steel interface (from *Met. & Mat. Transactions B*, 2001).

**Figure 2.** Direct observation of TiN inclusions in a transparent CaO-$Al_2O_3$ slag. TiN dissolution is accompanied by gas bubble formation.


**Figure 1**

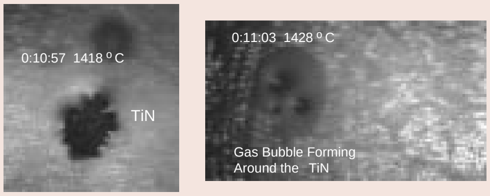


**Figure 2**

**Observation photographs. Developing an understanding of the practices and mechanisms responsible for the formation of large inclusions in cast steels.**

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ENERGY EFFICIENCY AND RENEWABLE ENERGY • U.S. DEPARTMENT OF ENERGY

## Project Description

**Goals:** To determine the methodology necessary to produce ultra-clean steels beyond that currently possible with today's technology. To understand the mechanisms behind inclusion removal at slag/metal interfaces and, based on this, develop methodology to improve the current limits of steel cleanliness (i.e. achieve oxygen levels less than 1 ppm and average inclusion diameters less than 5$\mu$m).

This research will be aimed at elucidating the factors that control inclusion formation and removal of both solid and liquid inclusions from liquid steels. The findings from this project will be used to determine the types of slags and interfacial conditions that are necessary to ensure complete separation of inclusions from steels at a slag metal interface and to determine the conditions that can lead to the formation of larger inclusions in steels. In this area, direct observation of phenomena at high temperatures is necessary. Confocal Scanning Microscopy will be used to elucidate the mechanisms responsible for inclusion agglomeration and removal. The finding will be compared to the limits of inclusion removal set by thermodynamics of the steel and slag.

**Objectives:**

- To determine the kinetic factors governing inclusion removal from liquid steels at slag/metal interface.
- To develop a methodology to enable steels with less than 1 ppm total oxygen content to be produced with an average inclusion diameter of less than five microns.
- To determine the slag/metal interface conditions necessary for ultra-clean steels.

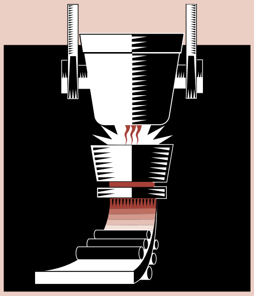
## Progress and Milestones

Specifically, the program will include the following tasks:

- Project start date, First Quarter 2001.
- Determine the factors controlling solid inclusion separation at a metal/gas interface, First Quarter 2002.
- Determine the factors controlling liquid inclusion separation and agglomeration at a slag/metal interface, Fourth Quarter 2002.
- Determine the factors controlling particle dissolution as a function of slag composition, Fourth Quarter 2002.
- Develop an understanding of inclusion morphology during re-oxidation with an oxidizing gas for various steel chemistries, Fourth Quarter 2003.
- Develop an understanding of the formation and separation of $MgO\text{-}Al_2O_3$ inclusions at a slag/metal interface, Fourth Quarter 2003.
- Develop a model to predict the time to produce a given steel cleanliness depending on slag and steel chemistries and temperature, First Quarter 2004.
- Project completion date, First Quarter 2004.

## Project Partners (Continued)

North Star Steel, Inc. – Cargill, Inc. Edina, MN
Stelco Inc., Hamilton, Ontario, Canada
The Timken Company, Canton, OH
United States Steel Research and Technology Center, Monroeville, PA



### Project Partners

Carnegie Mellon University, Center for Iron and Steelmaking Research
Pittsburgh, PA
(Principal Investigator)

American Iron and Steel Institute
Washington, DC
(Project Manager)

A.Finkl & Sons
Chicago, IL

Bethlehem Steel Corporation
Bethlehem, PA

Dofasco Inc.
Hamilton, Ontario, Canada

Gallatin Steel Company
Ghent, KY

Heraeus Electro-nite
Philadelphia, PA

LTV Steel Company
Cleveland, OH

### For additional information, please contact:

Gobind Jagtiani
Office of Industrial Technologies
Phone: (202) 586-1826
Fax: (202) 586-3237
gobind.jagtiani@ee.doe.gov
http://www.oit.doe.gov/steel

Please send any comments, questions, or suggestions to webmaster.oit@ee.doe.gov.
Visit our home page at www.oit.doe.gov.

Office of Industrial Technologies
Energy Efficiency
and Renewable Energy
U.S. Department of Energy
Washington, D.C. 20585

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