

## A Novel Flash Ironmaking Process

Advancing a Cost-Efficient Option to Produce Iron and Eliminate Cokemaking/Pelletizing Operations

Steel is used in a wide variety of manufactured products, such as skyscrapers, automobiles, and bridges. The coke oven/blast furnace process that produces pig iron for steelmaking requires additional energy to prepare the raw iron ore as sinter and pellets, and consumes large amounts of carbon which is emitted as the greenhouse gas *carbon dioxide*. Alternative processes can avoid some of these issues, but are limited by low production capacities and raw material restrictions. Therefore, the U.S. steel industry would benefit from the development of a low capital cost process, scalable to large capacities, that can take advantage of the availability of inexpensive iron ore concentrate, and can use fuels that significantly reduce potentially harmful greenhouse gas emissions.

The novel, high-intensity flash ironmaking process is a viable alternative that uses plentiful iron ore concentrates. The process would use inexpensive, abundant natural gas, or hydrogen, to produce hot reducing gas which burns at temperatures above 1300°C. When natural gas is used as the reducing agent, carbon can be added into the molten iron product, lowering its melting point and facilitating direct steelmaking in the same unit to maximize energy savings. Alternatively, the product could also be collected as a solid to be transported to an Electric Arc Furnace for steelmaking. Future system designs could provide up to 5.5% carbon for added benefits such as foamy slags that reduce heat loss, and improved tap-to-tap time.

A major advantage of flash ironmaking over existing ironmaking processes that use shaft or fluidized-bed furnaces is the elimination of sticking and particle fusion at high temperatures. The ability to use



Preliminary large-scale bench reactor facility layout. *Image courtesy of Berry Metal Company*

ore fines provides a cost advantage over processes that require ore to be agglomerated into pellets for ironmaking. The fine particles also cut the furnace's processing time to seconds. This translates to a smaller system for the same output, reducing both capital costs and operating costs. Other potential benefits include improved refractory life, and ease of feeding raw materials into the vessel.

### Potential Benefits for Our Industry and Our Nation

The flash ironmaking process would reduce energy consumption up to 20% over historical values by using iron oxide concentrates that do not require pelletization or sintering, and could eliminate the use of coke ovens. Greenhouse gas emissions could be significantly reduced by using natural gas or hydrogen as the reducing agent instead of coke. Preliminary estimates show that the use of natural gas would emit 39% less carbon dioxide than with a blast furnace-based process, while the use of pure hydrogen would emit almost no carbon dioxide.

### Applications in Our Nation's Industry

The flash ironmaking process could provide steel plants with significantly more energy-efficient and customized iron production facilities and could eventually replace blast furnace operations as we know them today.

### Project Description

The project objective is to conduct a comprehensive bench-scale testing campaign for the flash ironmaking process concept to:

- Validate the design concept of the flash ironmaking reactor in terms of heat supply and metallization degree.
- Determine optimum operating conditions in terms of reaction temperature, reducing gas composition, and particle residence time.

- Identify and address potential technical hurdles, such as refractory lining and iron powder collection.
- Identify and address potential safety challenges, including emergency shut-off procedures.
- Design an industrial-scale pilot plant.
- Estimate costs for the industrial-scale pilot system.

### Barriers

- Availability and implementation of inexpensive hydrogen.
- Reaching 1,300°C–1,600°C by reducing heat loss, achieving proper particle residence time, and identifying suitable refractory lining.

### Pathways

Researchers will construct a large-scale bench reactor and address administration, safety and operation issues. The reactor will be commissioned and validation tests performed. Bench-scale reactor design verification will commence following commissioning while experimental work continues using the existing small-scale lab flash reactor.

Large bench reactor testing will then be launched with natural gas as the fuel/reductant. Information regarding optimum operating temperature, gas velocity, reactor dimensions, and refractory type will be determined as a result of the testing. Optimum operating parameters will be established through designed experiments. The design team will use a physics-based analysis employing computational fluid dynamics and heat transfer to assist in the design of a pilot facility at industrial scale. The team will then provide a design concept with construction and operating cost estimates for an industrial scale pilot-plant.

### Milestones

This project began in 2012. Key milestones and project goals are:

- Complete commissioning of bench reactor by confirming temperature to be greater than 1,400°C, solid feed rate to be greater than 1 kg/hr, and operation time to be greater than 6 hours (2014).
- Achieve greater than 95% metallization with 1.5 times the theoretical minimum amount of reducing gas (2015).
- Determine optimum conditions for the flash ironmaking process (2015).

- Outline cost estimates and preliminary design for industrial pilot plant (2015).

## Commercialization

The American Iron and Steel Institute (AISI) has the expertise and will be responsible for formulating a commercialization plan. Options regarding the pilot plant will be provided and considered by the steel industrial participants. If a commercial partner is identified earlier in the process, this partner may participate in the design and construction of the pilot facility. AISI will also maintain and coordinate intellectual property activities regarding patents by means of a holding company. Initial entry into the mainstream market will likely be via steel manufacturing facilities looking for a more cost-efficient alternative ironmaking process with reduced carbon emissions.

## Project Partners

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