A Novel Flash Ironmaking Process

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American Iron and Steel Institute/University of Utah

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Project Objective

- Develop a new ironmaking process w/ significant reduction in energy consumption and CO_2 generation
- Blast furnace requires pelletization and/or sintering of iron ore concentrate
- Consumes large amounts of energy and carbon $\rightarrow$ CO_2 emissions
- Alternative ironmaking processes must have:
  - Large production capacities (e.g., ~1,000,000 tpy of iron)
  - Use the main raw material (i.e., iron ore) with minimal pretreatment

Technical Approach

Current practice

- Blast furnace (BF) produces >90% iron for steelmaking
- BF needs large capital investments
- High energy consumption in raw materials preparation and CO_2 emissions
- Use of special coals for cokemaking

New Approach – A Novel Flash Ironmaking Process

- Direct use of iron concentrate (~30 μm)
  - Bypass pelletizing and sintering
- Use of inexpensive, abundant natural gas [or hydrogen, coal gas]
  - No cokemaking required
  - Lower energy consumption
  - Less CO_2 emissions
- Rapid reaction rate and favorable Net Present Value (NPV)

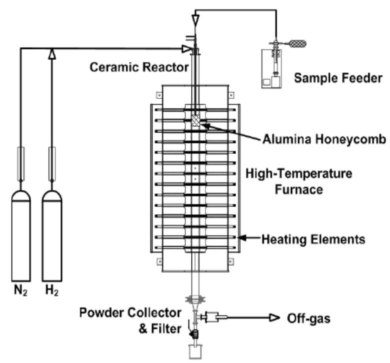
Technical Approach

- Install, commission & conduct test on a new large bench reactor at the University of Utah

Large-Scale Bench Reactor Facility: Preliminary Layout - Image courtesy of Berry Metal Company

- Multidisciplinary team:
  - American Iron and Steel Institute
    - ArcelorMittal USA
    - The Timken Company
    - United States Steel Corporation
  - University of Utah (Lead Research Organization)
  - Berry Metal Company (Bench reactor fabrication)

Transition and Deployment

Project Objectives	**Kinetic Feasibility** Technology Road Map (2005-2007)	**Proof of Concept at Lab Scale** AISI CO_2 Breakthrough (2008-2011)	**Process Validation/ Scale-up** Innovative Manufacturing Initiative (2012-2015)	**Industrial Pilot** TBD (2016+)
Experimental Apparatuses				Approaches 1. Large scale 75-100k tpy 2. Modest-scale: 10-25k tpy 3. Expand U of Utah work: Similar to bench reactor but larger
Funding	Federal, $350k **Industry, $150k** Total, $500k	Federal, $ 0 **Industry, $ 4.8million** Total, $4.8million	Federal, $ 7.1million **Industry, $ 1.8million** Total, $8.9million	$10 – 75million **Funding TBD**

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Transition and Deployment

- Benefits steel users and steel-related industry
- U.S. Steel industry would be the end user
- To be used to produce iron as a raw material for steelmaking resulting in:
  - Direct use of iron ore concentrate
  - Low capital cost
  - Scalable to large capacities
  - Avoidance of cokemaking
- Commercialization through licensing & royalty
- Sustainable as a more energy efficient and green ironmaking step

Measure of Success

- If successful, iron will be produced at a lower cost, using less energy, and emitting less CO_2
- Potential energy savings: ~3.5 GJ/ton Fe vs. avg. BF
- CO_2 emission: Less than 36% vs. avg. BF process

Metric	H_2-based process	Reformerless natural gas process	Blast Furnace process
Energy Requirement (GJ/ton of hot metal)	11.3	14.5	18.0
CO_2 emission (tons/ton of hot metal)	0.04	1.02	1.60

- *NPV for standard case (15 year period): $401M (2010)/(1 M tpy) Natural gas cost: $5/M (2010) BTU HHV*

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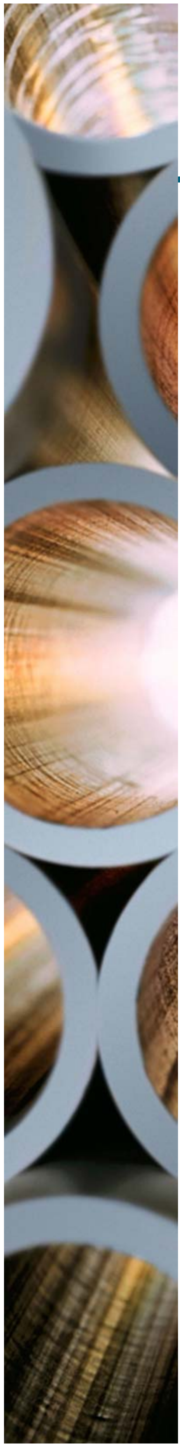
Project Management & Budget



Task	Description	Milestones: Key Inputs	Criteria	Date
1	**Bench Scale Reactor**	**Go/No Go Decision # 1:**		1/31/2015
	– Installation	Operating Temperature	1400°C	
	– Commissioning	Solid feed rate	>1 kg/hr	
		Operation time	>6 hr	
2	**Testing Program**	**Go/No Go Decision # 2:**		7/31/15
	– Existing lab flash reactor	Metallization	95%	
	– Drop-tube reactor	Min. amt. reducing gas	3.0x	
	– Bench reactor	**Go/No Go Decision # 3:**		1/31/16
	– CFD model	Metallization	95%	
		Min. amt. reducing gas	1.5x	
		Milestone # 4:		7/31/16
		Metallization	95%	
		Solid feed rate	>5 kg/hr	
3	**Industrial pilot reactor**			
	– Design			
	– Cost estimate			
4	**Program Administration**			1/31/17

Total Project Budget	
DOE Investment	$7,120,000
Cost Share	$1,780,000
Project Total	$8,900,000

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Results and Accomplishments

- Fabricated New bench reactor and ancillary equipment
- Designed/fabricated main burner – key component
- Prepared site for bench reactor installation

- Achieved 80-95% metallization in existing lab reactor*
- Fuel/reductant: Hydrogen
  - [Natural gas tests are planned]
- Reaction time: 4-6 seconds
- Temperature: ~1200°C
  - [less than 1300°C in bench reactor]


Existing Lab reactor at the University of Utah

Different from New Bench Reactor with respect to the size and material of construction, which limits the operating temperature. Solid feed rate is limited (~ **0.5 kg/hr).*

Results and Accomplishments

- Measurement of reduction kinetics with natural gas using existing Lab reactor (2014)
- Computational Fluid Dynamic model development (2014-2016)
- Installation of new bench reactor (1Q15)
- Testing with new bench reactor (2015-2016)
- Industrial pilot plant design (2016)