A Novel Flash Ironmaking Process

DE-EE0005751

American Iron and Steel Institute/University of Utah

09/01/2012 - 07/31/2017

Joseph Vehec, American Iron and Steel Institute

U.S. DOE Advanced Manufacturing Office Program Review Meeting
Washington, D.C.
May 28-29, 2015

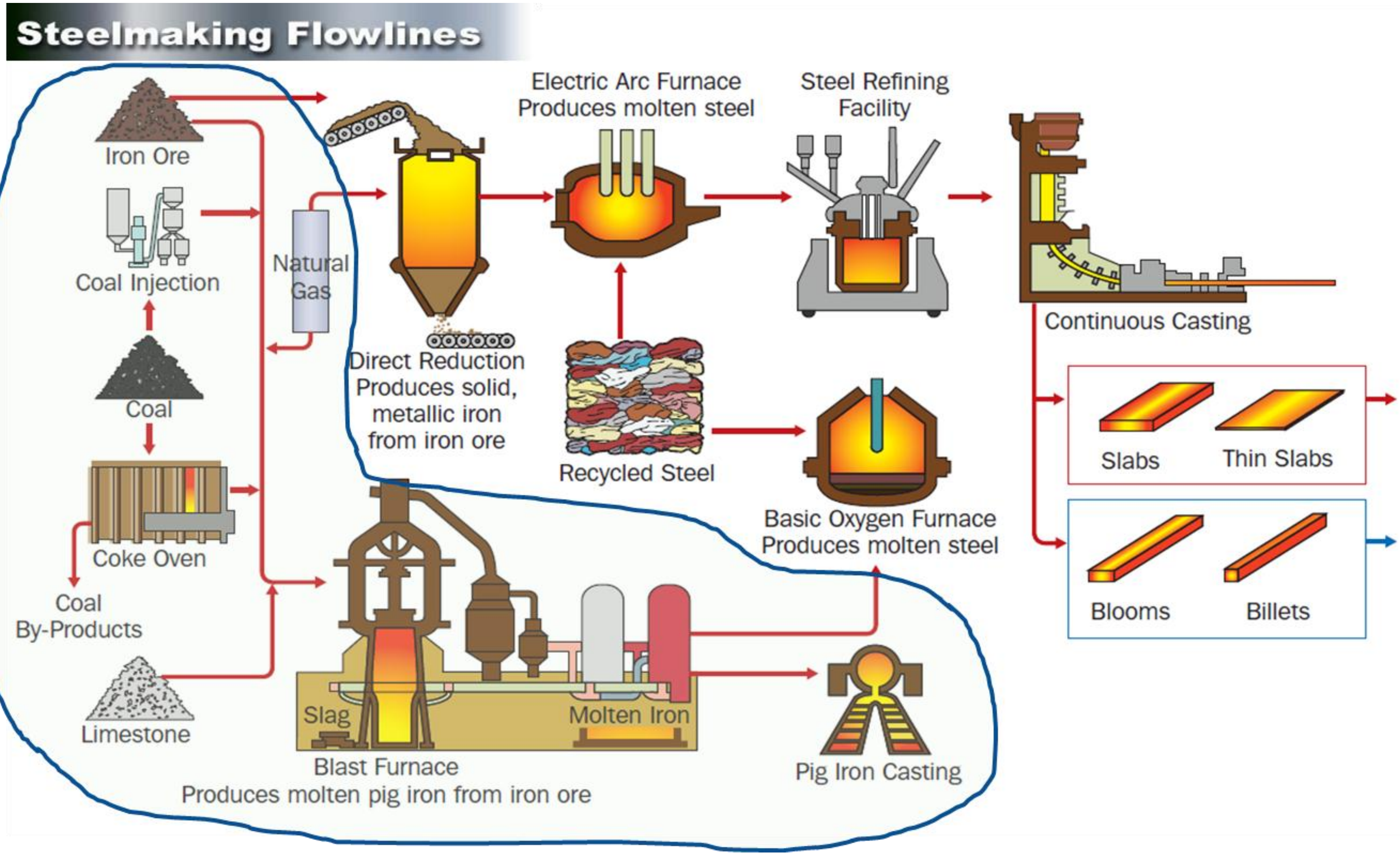
American Iron and Steel Institute

The New Steel

Project Objective

- Develop a new ironmaking process with significant reduction in energy consumption and CO_2 generation
- Blast furnace requires coke and 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



Novel Flash Ironmaking replacing cokemaking and Blast Furnace

American Iron and Steel Institute

The New Steel

Technical Approach

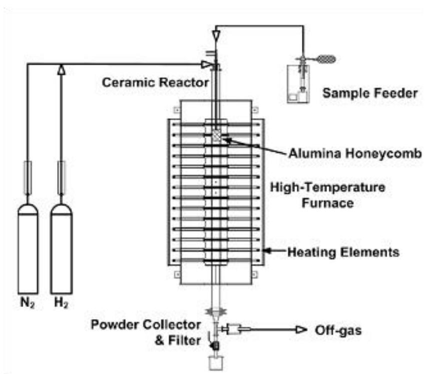
- Install and commission Large-Scale Bench Reactor
- Comprehensive testing program
- Industrial pilot plant design
- Multidisciplinary team:
  - American Iron and Steel Institute
    - ArcelorMittal USA
    - TimkenSteel
    - United States Steel Corporation
    - Berry Metal Company
      - Bench reactor fabrication
    - University of Utah
      - Lead Research Organization

Large-Scale Bench Reactor
(Image courtesy of Berry Metal Company)

American Iron and Steel Institute

The New Steel

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 (2012-2017)	**Industrial Pilot** **TBD** (2017+)
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, $ 8.0 million **Industry, $ 2.6 million** Total, $10.6 million	$10 – 75million **Funding TBD**

Transition and Deployment

- Benefits steel users and steel-related industry
  - US Steel industry would be the end user
- 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 process

Measure of Success

- If successful, will produce iron at a lower cost using less energy and emit less CO_2
- Potential energy savings: ~3.5 GJ/ton Fe vs. avg. Blast Furnace
- CO_2 emission: < 36% vs. avg. Coke Oven/Blast Furnace route

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*

Project Management & Budget

Task	Description	Milestones: Key Inputs	Criteria	Date
1	**Bench Scale Reactor**	**Go/No Go Decision # 1:**		7/31/2015
	-Installation	Operating Temperature	1400°C	
	-Commission	Solid feed rate	>1 kg/hr	
		Operation time	>6 hr	
2	**Testing Program**	**Go/No Go Decision # 2:**		11/30/15
	-Existing Utah flash reactor	Metallization	95%	
	-Drop-tube reactor	Min. amt. reducing gas	3.0x	
	-Large Scale Bench Reactor	**Go/No Go Decision # 3:**		5/31/16
	-CFD model	Metallization	95%	
		Min. amt. reducing gas	1.5x	
		Milestone # 4:		11/30/16
		Metallization	95%	
		Solid feed rate	>5 kg/hr	
3	**Industrial pilot reactor**			4/30/17
	-Design and Cost estimate			
4	**Program Administration**			7/31/17

Total Project Budget	
DOE Investment	$ 8,000,000
Cost Share	$ 2,600,000
Project Total	$10,600,000

American Iron and Steel Institute

The New Steel

Results and Accomplishments

- Completed formulation of CFD model for operation at different temperatures, gas compositions, and particles
- Achieved 80-95% metallization
  - Fuel/reductant: Hydrogen or Methane
  - Reaction time: 4-7 seconds
  - Temperature: ~1200° C → Target 1300° C
  - Solid feed rate: 0.1 – 0.2 kg/h
- Determined the kinetics of magnetite reduction with hydrogen using drop tube reactor at 1400 - 1600° C

Next Steps

- Complete installation and commission large-scale bench reactor - July 2015
- Large-Scale Bench Reactor tests with Natural Gas - 2015/2016
  - Generate information on optimum operating temperature, gas velocity, reactor dimensions, and refractory type
- Industrial pilot plant design - April 2017
  - Construction of flow sheets
  - Complete material and energy balances
  - Design and cost estimate

Large Scale Bench Reactor