Novel Flash Ironmaking Technology (FIT)

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Flash Ironmaking Technology (FIT)  
(FIT for H2@Scale)

$\text{Fe}_3\text{O}_4 + (\text{H}_2, \text{CO}) \rightarrow \text{Fe} + (\text{H}_2\text{O}, \text{CO}_2)$

Gas-Solid Suspension Reduction  
Hydrogen or Natural Gas

✓ Fine iron ore WITHOUT  
Coke/Pelletization/Sintering

✓ Significant Reduction in $\text{CO}_2$ 
& Energy Consumption

✓ Replace BF

Direct steelmaking process  
based on Flash Ironmaking
Flash Ironmaking Technology (FIT) – cont’d

- Process based on proven flash technology, e.g. copper smelting furnaces
- Applicable to iron ore concentrates; magnetite from taconite, hematite-bearing jaspers, etc.
- Reducing/fuel gases include $H_2$ and $CH_4$
- Magnetite taconite is the principal iron ore in the U.S.
- In 2008, the gross ore production in the U.S. was 54 MM tonnes.
- Minnesota (Mesabi Range) and Michigan (Marquette Range) mines account for almost all U.S. iron ore production.

Taconite ore: 70% concentrate, <100 µm
# What Now and Next

## Project Objectives

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<th>Kinetic Feasibility</th>
<th>Proof of Concept at Lab Scale</th>
<th>Process Validation/Scale-up</th>
<th>Industrial Pilot TBD</th>
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## Experimental Apparatuses

1. **Large scale**: 75-100k tpy
2. **Modest-scale**: 10-25k tpy
3. Expand U of Utah work: Similar to bench reactor but larger

## Approaches

<table>
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<th>Funding</th>
<th>Approaches</th>
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| **Federal, $350k**  
Industry, $150k  
Total, $500k | 1. Large scale  
75-100k tpy |
| **Federal, $0**  
Industry, $4.8M  
Total, $4.8M | 2. Modest-scale:  
10-25k tpy |
| **Federal, $8.0**  
Industry, $2.6M  
Total, $10.6M | 3. Expand U of Utah work: Similar to bench reactor but larger |
| **$10 - 75M**  
Funding TBD | |
Flash Ironmaking Process

Pilot-scale furnace testing & demonstration

- Reduction with partial oxidation of natural gas, 1,200-1500°C
- Dimensional and residence time relative to commercial plant
- $10.6 Million cost-share project

Current Partners:
- AISI / DOE
- ArcelorMittal USA
- Berry Metal Co.
- Timken Steel
- U. S. Steel
- University of Utah
FIT produces non-pyrophoric iron

Flash reduced iron at 1623 K (1350 °C)

H₂-reduced iron at 1073 K (800 °C)
Commercial-Scale Plant Modeling

- One-step and Two-step commercial-scale reformerless ironmaking process
- 1 million tons annual output, 300 day/yr operation
- 1,500 °C operation
- Excess driving force = 0.5
- METSIM process model
Carbon dioxide emission from ore/coke preparation is not included.

% of BF = 2.5 % (H₂); 64 % (Natural Gas w/o Reformer)

Energy Requirement
*(GJ per metric ton molten iron)*

- Avg. Blast Furnace: 12.7 GJ/ton molten iron
- Flash Ironmaking (Hydrogen): 5.7 GJ/ton molten iron
- Flash Ironmaking (Natural Gas, w/o Reformer): 8.9 GJ/ton molten iron
- Flash Ironmaking (Natural Gas, w/ Reformer): 12.9 GJ/ton molten iron

Pelletizing = 3; Sintering = 0.7; Cokemaking = 2
% of BF = 45 % (H₂); 70 % (Natural Gas w/o Reformer)
Economic Feasibility – Hydrogen

- Hot metal price: $512/ton
- Hydrogen cost: $2.5/kg-H₂ (2010)
- 500,000 tons/yr hot metal
- 15 year capital project
- 10% discount rate

NPV = (minus $546 million), no CO₂ credit
NPV = $48 million, with $50/ton CO₂ credit

H. K. Pinegar, M. S. Moats, H. Y. Sohn
“Process Simulation and Economic Feasibility Analysis for a Hydrogen-Based Novel Suspension Ironmaking Technology”
Steel Research Int. 82, 2011, No. 8.
Financial Feasibility – Natural Gas

- Hot metal price: $512/ton
- 1 million ton hot metal/year
- Natural gas feed: $5/million Btu
- 15 year capital project
- 10% discount rate

NPV = $401 for Reformerless one-step process
NPV = $214 for SMR Hydrogen Process

H. K. Pinegar, M. S. Moats, H. Y. Sohn
“Flowsheet development, process simulation and economic feasibility analysis for novel suspension ironmaking technology based on natural gas: Part 3 – Economic feasibility analysis”
Iron and Steelmaking 2013 vol.40 No.1
Potential Implications

- H₂ Requirement = 0.1 ton / ton iron

- Rate of Iron Production (2015):
  U.S.+ Canada = 32.5 million tons/year
  World = 1.2 billion tons/year

- H₂ Equivalent:
  U.S.+ Canada = 3.3 million tons/y = 3.7x10¹⁰ m³/y
  World = 120 million tons/y = 130x10¹⁰ m³/y

- Reduction in CO₂ Emissions:
  U.S.+ Canada = 54 million tons/y
  World = 2 billion tons/y
Summary

- Low CO$_2$ emissions: 2.5% of BF ironmaking (w/ H$_2$)
- Energy saving: 3.0 GJ/ton Fe (55%) cf. BF (w/ H$_2$)
- Eliminate cokemaking and pelletization/sintering & associated pollution.
- 90-99% reduction in 2-7 seconds at 1200-1500°C
- Enormous hydrogen utilization potential