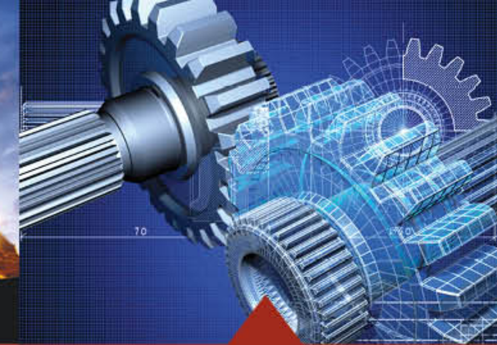


BOF | EAF | Blast Furnace | Engineering / Innovations

U.S. DEPARTMENT OF ENERGY
H2@SCALE WORKSHOP
AUGUST 1, 2018
THE USE OF HYDROGEN IN THE IRON AND STEEL INDUSTRY

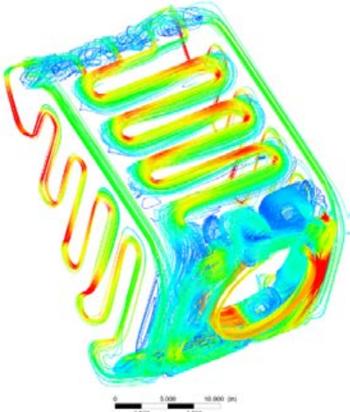
Presented by Ed Green

Berry METAL COMPANY

Advanced Iron & Steelmaking TECHNOLOGIES

BERRY METAL COMPANY

- Over 65 years of experience
- Experience in EAF, BOF and Blast Furnaces
- ISO 9001:2008 Certified
- Over 75 Patents, several Pending
- Locations (Pittsburgh & Greater Chicago Area)
- Equipment Engineering and Manufacturing Company
- OEM Supplier of Components
- On-Site Technical Support
- Continuous Product Improvements



THE USE OF HYDROGEN IN THE IRON AND STEEL INDUSTRY

STEEL MAKING TECHNOLOGIES AND PROCESSES FOR IRON FEEDSTOCK

- BOF – Basic Oxygen Furnace
  - BF - Blast Furnace
  - SR – Smelting Reduction
- EAF – Electric Arc Furnace
  - Scrap steel
  - DRI – Direct Reduced Iron

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Chemical Processes to Reduce Iron Oxide

Reduction by CO

- $Fe_3O_4 + CO = 3FeO + CO_2$
- $FeO + CO = Fe + CO_2$

Consumes 500 Nm^3/t_{iron} of CO

Reduction by H_2

- $Fe_3O_4 + H_2 = 3FeO + H_2O$
- $FeO + H_2 = Fe + H_2O$

Consumes 500 Nm^3/t_{iron} of H_2

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BLAST FURNACE

- BF/BOF - **B**last **F**urnace feeding a **B**asic **O**xygen **F**urnace has dominated the ironmaking process since the 1980s.
- Environmental regulations are causing a significant decline of the BF method of making iron.
- Although still the base source of virgin iron, new blast furnaces have not been built in the U.S. in decades and there are no plans to build one anytime soon. The U.S. steel industry is currently undergoing transformation.

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ELECTRIC ARC FURNACE
SCRAP & DIRECT REDUCED IRON

- EAF - **E**lectric **A**rc **F**urnace for steel making is a rapid growing technology competing with the BF/BOF
- Major feedstock is scrap steel
- The purity of existing scrap steel is declining and needs virgin iron added to dilute the tramp elements such as copper and zinc to improve final product quality
- DRI – **D**irect **R**educed **I**ron is one of the iron products added to the scrap to increase purity
- DRI is iron ore that has been reduced to iron with syngas without melting
- DRI processes in U.S. generally use natural gas to reduce the ore

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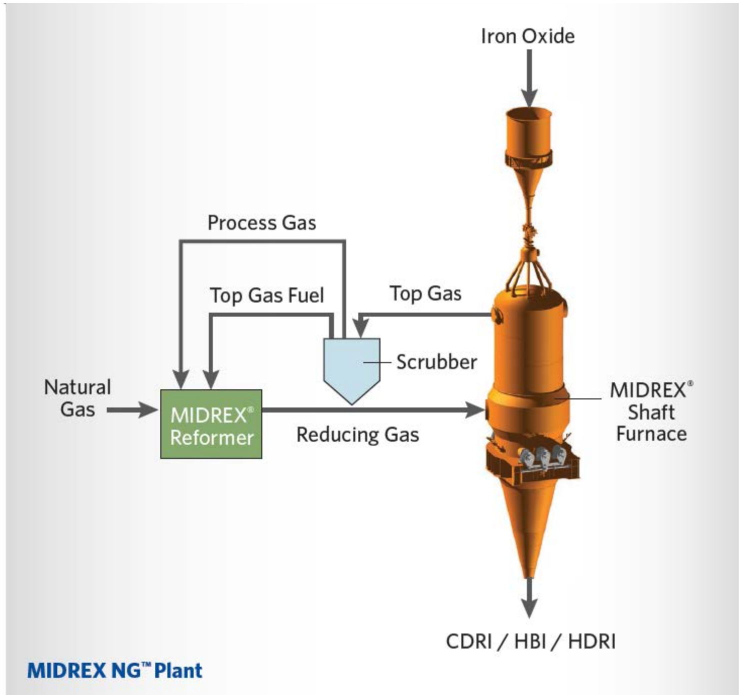
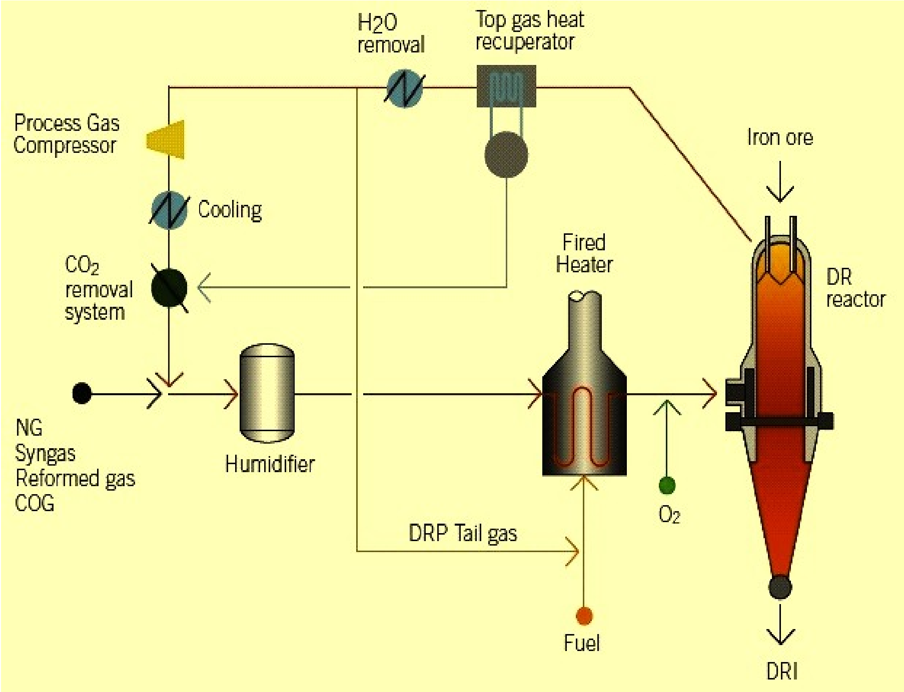
Established DRI Technology Competing with BF/BOF

Midrex
Reformer outside of reactor
Creating syngas H2 & CO

HYL III
Partial oxidation of gas entering reactor
Creating syngas H2 & CO





Depictions taken from IETD Industrial Efficiency Technology Database

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FLASH IRONMAKING TECHNOLOGY USING HYDROGEN

Current Partners

American Iron and Steel Institute

U.S. Department of Energy

Berry Metal Company

ArcelorMittal USA

TimkenSteel

U.S. Steel

University of Utah

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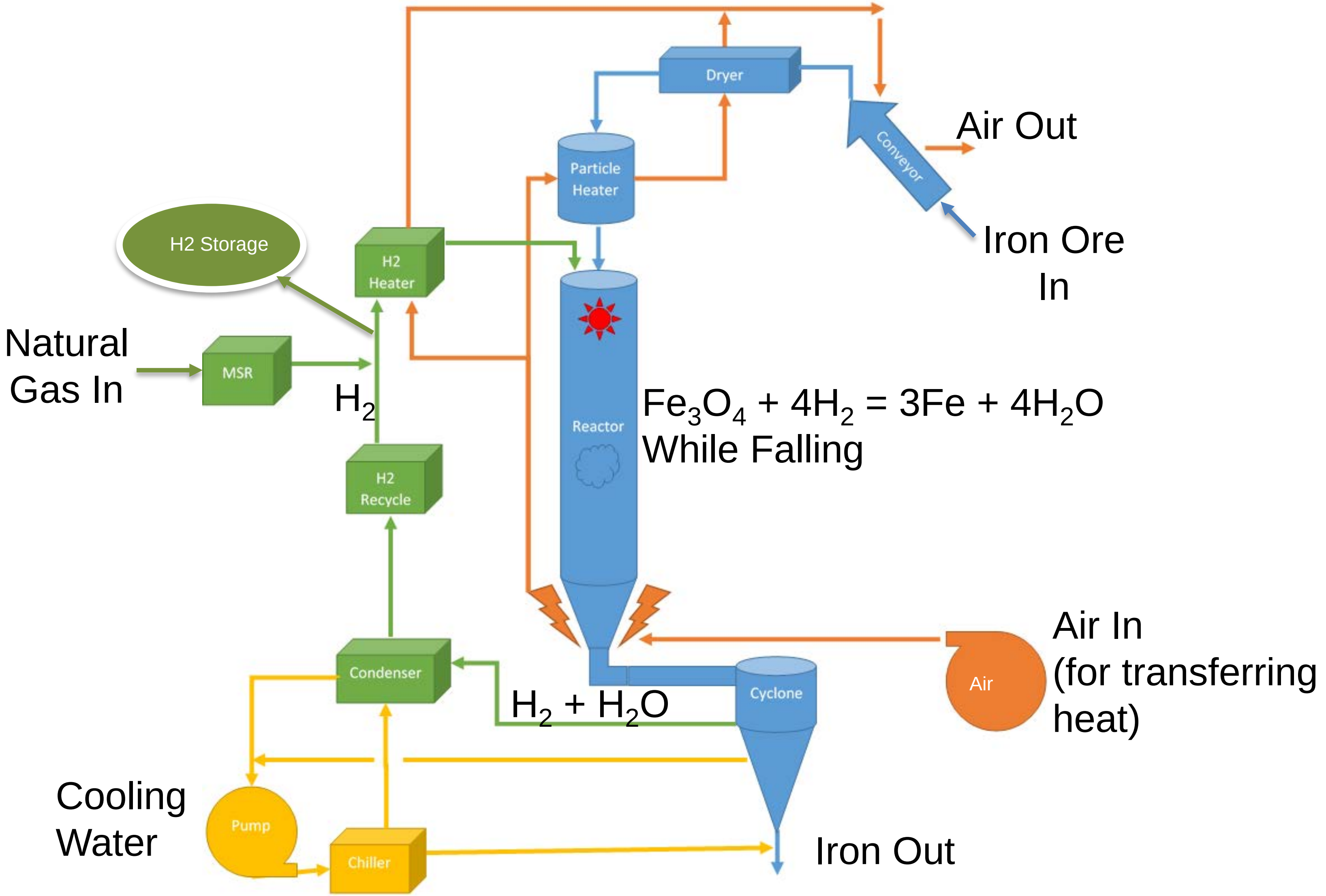
Flow Diagram for Flash Ironmaking Plant



Energy Usage for Ironmaking Comparison of Existing Reduction Methods

Method	Energy Usage
Blast Furnace	16.7 GJ/t
Midrex	10.4 GJ/t
HYL III	10.4 GJ/t
Flash Ironmaking	**10.8 GJ/t**
Iron Carbide Process	12.6 GJ/t
Finmet	12.4 GJ/t
Circored	11.5 GJ/t

Data taken from IETD Industrial Efficiency Technology Database

10.8 GJ/t is a conservative calculation based on maximum users during commercial scale operations. Actuals could be lower.

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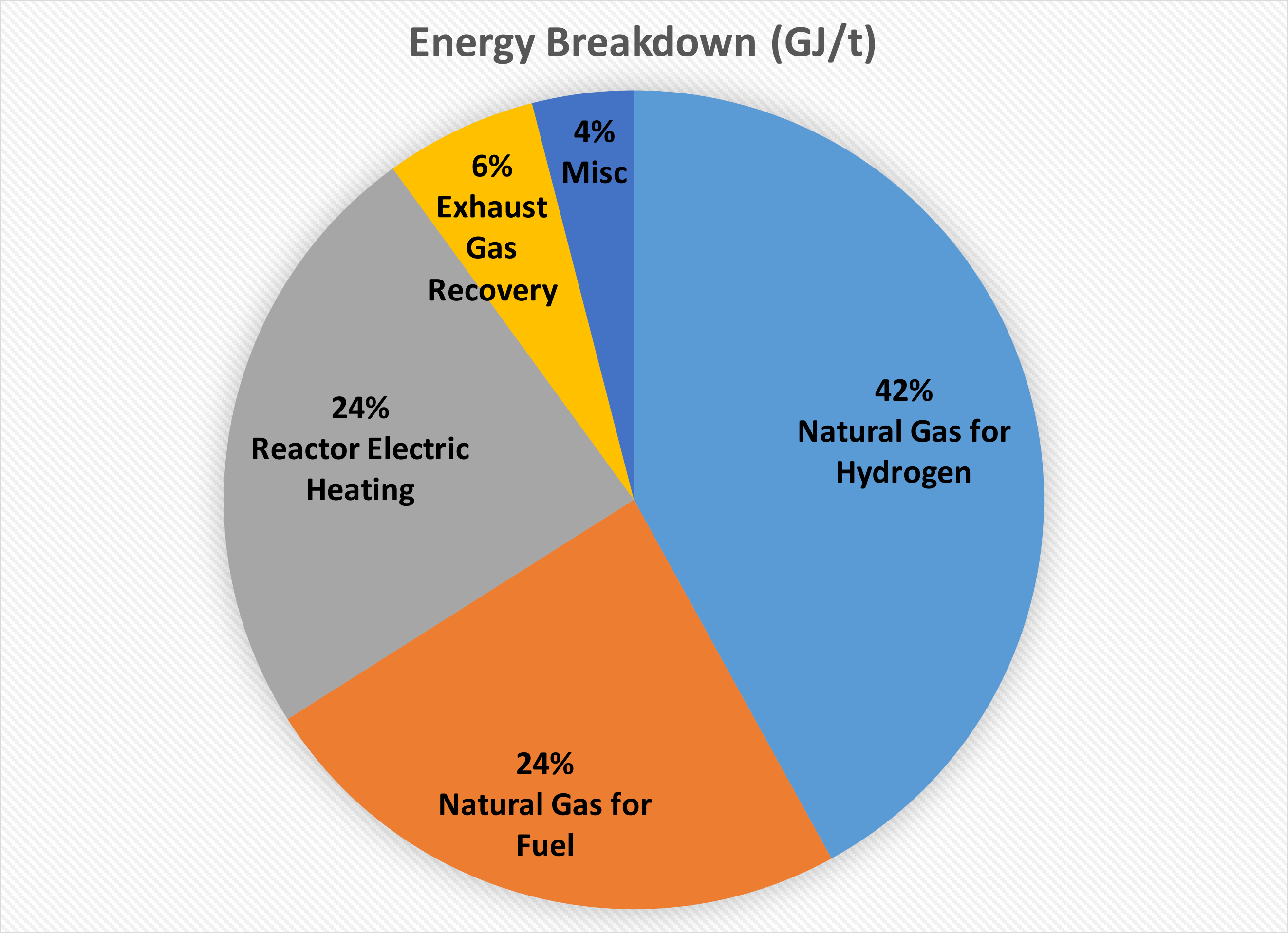
FLASH IRONMAKING ENERGY BREAKDOWN 10.8 GJ/t



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OPERATING PROFILES

Blast Furnace

Operating temperature 250C @top to 1650C @bottom

Residence time is 8 to 10 hrs

DRI Furnace

Operating temperature1090C

Residence time is 10 to 12 hrs

Flash Ironmaking Furnace

Operating temperature 1325C

Residence time is 2 to 10 seconds

Residence time is a combination of speed of reaction due to temperature, size of the feed material and amount of excess gas/distance from equilibrium line

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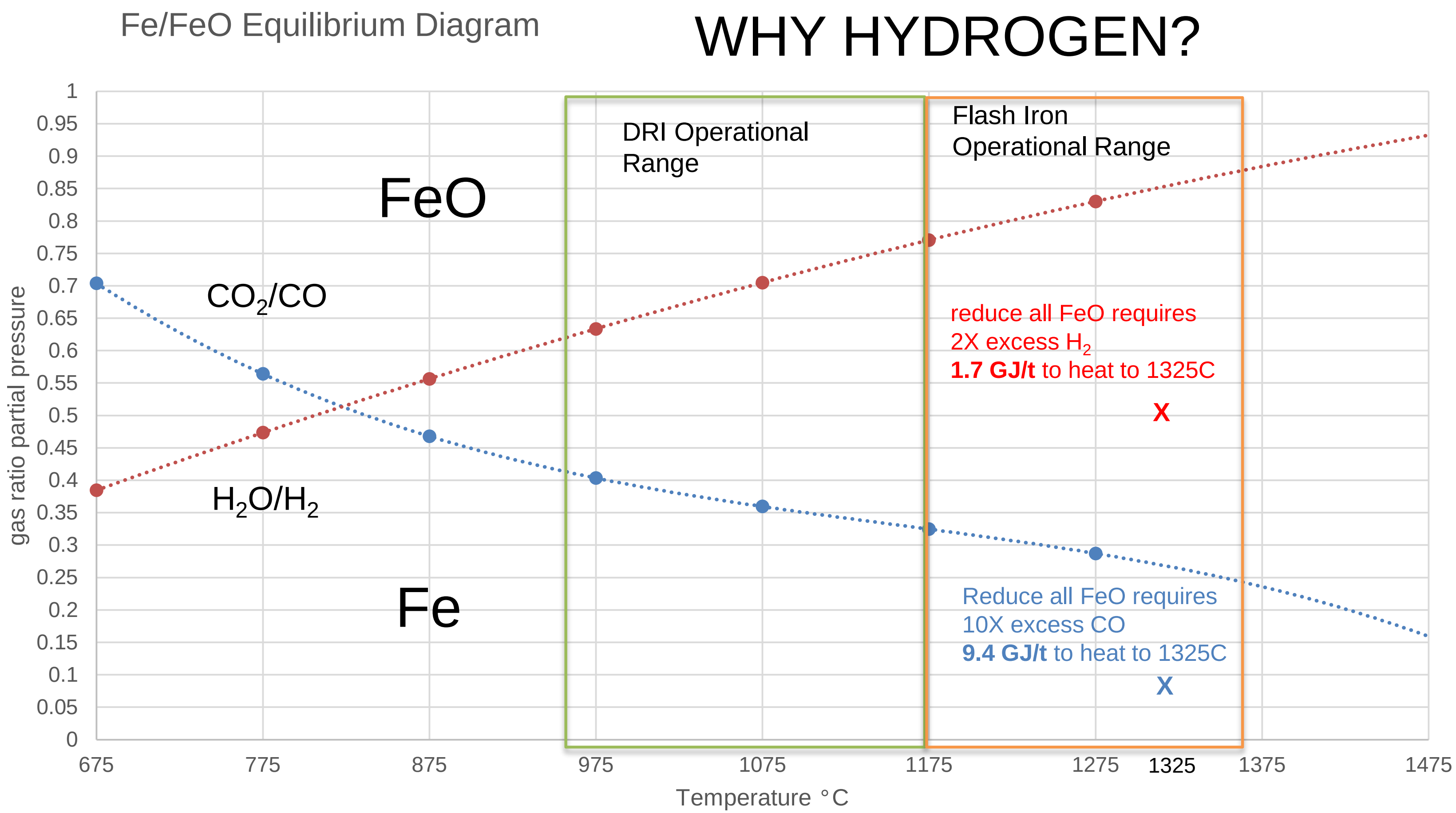
WHY HYDROGEN?



- Low temperatures CO more effective at reducing FeO
- High temperatures H_2 more effective at reducing FeO