CO₂ Ultimate Reduction in Steelmaking Process (COURSE50 Project)

COURSE50 : CO₂ Ultimate Reduction in Steelmaking process by Innovative technology for cool Earth 50


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Overview of R&D Activities in COURSE50

(1) Technologies to reduce CO₂ emissions from blast furnace
- Coke production technology for BF hydrogen reduction
- Coke substitution reducing agent production technology
- Reaction control technology for BF hydrogen reduction
- Iron ore pre-reduction technology
- Shaft furnace
- COG reformer
- Coking plant
- High strength & high reactivity coke

(2) Technologies for CO₂ capture
- Chemical absorption
- Physical adsorption
- CO₂ storage technology
- CO-rich gas
- Regeneration Tower
- Reboiler
- Absorption Tower
- CO₂ capture technology

Other project
- Electric power generation
- Technology for utilization of unused waste heat
- Sensible heat recovery from slag (example)
- Waste heat recovery boiler
- BOF
R&D Organization

Contract Research

NEDO*

Commission

The COURSE50 Committee of JISF (Japan Iron and Steel Federation) supports the research and development activities of the 5 integrated steel companies.

*NEDO: New Energy and Industrial Technology Development Organization (National Research and Development Agency)
## Approach Methods

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R&D Schedule

2008 | 2012 | 2013 | 2017 | 2020 | 2030 | 2040 | 2050
---|---|---|---|---|---|---|---

**Phase 1 STEP 1 (5 years)**
Development of basic technologies
[Total budget: 10 billion yen]

**Phase 1 STEP 2 (5 years)**
Integrated development of CO₂ reduction technologies
[Total budget: 15 billion yen]

COURSE 50 aims at developing technologies to **reduce CO₂ emissions by approximately 30%** through suppression of CO₂ emissions from blast furnaces and capture, separation and recovery of CO₂ from blast furnace gas (BFG), and establishing the technologies **by ca. 2030** with the final goal of industrializing and generalizing the developed technologies **by 2050**.

Commercialization of first unit by around 2030*

Industrialization & transfer

**Phase 2**
Practical development

*Based on assumption that CO₂ retaining infrastructure and commercialization are economically rationalized.
Concept of Iron Ore Hydrogen Reduction Reinforcement

**Conventional BF vs COURSE50 BF**

**CO Indirect Reduction**: Exothermic reaction
\[ \text{FeO} + \text{CO} \rightarrow \text{Fe} + \text{CO}_2 + 17288 \text{kJ/kmol} \]

**H₂ Indirect Reduction**: Endothermic reaction
\[ \text{FeO} + \text{H}_2 \rightarrow \text{Fe} + \text{H}_2\text{O} - 23834 \text{kJ/kmol} \]

**Carbon Direct Reduction**: Large Endothermic reaction
\[ \text{FeO} + \text{C} \rightarrow \text{Fe} + \text{CO} - 155011 \text{kJ/kmol} \]

**H₂ reductant**

We develop technologies to control reactions for reducing iron ore by use of H₂ reductant to decrease carbon consumption in BF.
Hydrogen Reduction Trial in LKAB Experimental BF

Trial: 16th April to 11th May, 2012

- Basket Sample
- Vertical Probe
- Upper Probe
- Lower Probe
- Inclined Probe

Ferrous Material:
- Sinter 70% - Pellet 30%
- Coke and pulverized coal: from SSAB

- Upper Shaft Tuyere
- Hot Top Gas Injection
- Reformed COG Injection Shaft Tuyere
- Blast Tuyere COG Injection

Figures from Swerea/MEFOS and LKAB brochure
Results of Hydrogen Reduction Trial

H2 reduction increased in both COG injection from the blast tuyeres and reformed COG injection from the shaft tuyeres because of the fast reaction rate of H2 reduction.

- Carbon direct reduction decreased, which is a huge endothermic reaction; this is the main reason for the reduction in carbon input.
Results of Oxygen Potential in the Blast Furnace

- Upper shaft tuyeres
- Hot top gas
- Upper shaft probe
- Lower shaft tuyeres
- RCOG
- COG

Graph: Calculated $p_O_2$ based on CO/CO$_2$ reaction (atm) vs. Estimated $p_O_2$ based on $H_2/H_2O$ reaction (atm). The graph shows data points for COG Inj. upper, COG Inj. lower, RCOG Inj. upper, and RCOG Inj. lower.
New Experimental Blast Furnace

Sequential operation

CO₂ separation plant

Absorber
Stripper
Reboiler

CAT30 (30t-CO₂/d)

New Experimental Blast Furnace (10m³ Scale)
Location of New Experimental Blast Furnace

Experimental Blast Furnace

CO₂ Separation Plant (CAT-30)

Kimitsu 4BF

NSSMC Kimitsu Works
Schematic View of New Experimental Blast Furnace

- Funace Top
- Shaft Sonde (Three levels)
- Injection tuyere of pre-heating gas
- Shaft tuyere
- tuyere
- Tap holl
Photo of New Experimental Blast Furnace
Inside of Experimental Blast Furnace

tuyere
Pre-test Operation results of Experimental BF
Pre-test operation of experimental BF

12/8 1:20-1:45 (HMT: 1300°C of first tapping. [C]=3.72%, [Si]=2.36%, [S]=0.169%
TGP 50kPa, BV 1000Nm³/h,

12/8 6:55-7:02 (3rd tapping) 1400°C
[C]=4.28%, [Si]=1.62%, [S]=0.065%
TGP 100kPa, BCV1530Nm³/h
Pathway to the Target

Several candidates come under review.

- Improvement of coke
- Improvement of raw materials
- Improvement of blast conditions
- Simple application of COG
Concluding Remarks

COURSE50 aims at developing new drastic CO₂ reduction technologies. The CO₂ emissions reduction target is approximately 30% in the steel works.

The project aims to achieve this reduction through iron ore reduction by using coke oven gas (hydrogen resource containing) to suppress CO₂ emissions from blast furnaces, in combination with separation and recovery of CO₂ from blast furnace gas by using unused waste heat in the steel works.

The project completed the development of the basic technologies in STEP 1 (2008-2012) according to schedule, and is now engaged in the development of the comprehensive technologies in STEP 2 (2013-2017).

The goal of the project is to establish the CO₂ reduction technologies which contribute technically to commercialize the first unit by around 2030 and to generalize the technologies by 2050, considering the timing of the replacement of blast furnace equipment.