GC8000 Analyzer System Contributing to Environmentally Harmonized Steelmaking Process Technology Development (COURSE50)

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Currently, the Japanese steel industry has been working on a long-term national project named "Environmentally Harmonized Steelmaking Process Technology" (CO_2 ultimate reduction in steelmaking process by innovative technology for cool earth 50: COURSE50) as a global environment preservation activity for the reduction of CO_2 emissions in an industry-government-academia integrated collaboration. We have performed measurements of pressure, temperature, and components of the top and internal points of a test blast furnace by applying a gas chromatograph GC8000 to an analyzer system. With the analyzer system, we achieved the horizontal distribution monitoring of gas components, temperature and pressure at each part of the test blast furnace which was filled with solid materials, thus enabling the CO_2 emission reduction during the test to be quantitatively determined.

This paper outlines the COURSE50 project and the test blast furnace measurement, and introduces the analyzer system using a gas chromatograph GC8000 which played an important role in the comprehensive verification tests at the pilot level.

INTRODUCTION

As global warming is becoming a serious concern, Japan has a great responsibility and obligation as a leading industrialized country. Tackling global warming requires a global effort, including developing technologies for reducing CO_2 emissions and saving energy. The Cool Earth 50 initiative [i] announced in 2007 proposes to "achieve compatibility between environmental protection and economic growth by utilizing energy conservation and other technologies." Among innovative technology development programs, the "CO_2 Ultimate Reduction in Steelmaking Process by Innovative Technology for Cool Earth 50: COURSE50" project was launched to achieve the goal of the Cool Earth 50 initiative [(1)].

CO_2 emissions by the steel industry account for 40% of the total by industry in Japan, of which 70% comes from the steelmaking process using blast furnaces. However, the steel industry in Japan is already the most energy-efficient in the world, leaving little room for reducing CO_2 emissions; innovative technologies are needed for further reductions. The COURSE50 aims to develop technologies for reducing CO_2 emissions by approximately 30% by suppressing emissions as well as capture, separation, and recovery of CO_2. This project aims to establish the technologies by 2030 and then industrialize and disseminate them by 2050 [(1)(2)].

Currently, the COURSE50 is at Step 2 (fiscal 2013 to 2017) and technologies are being developed in an industry-government-academia collaborative project named "Environmentally Harmonized Steelmaking Process Technology Development" commissioned by the New Energy and Industrial Technology Development Organization (NEDO) [(2)]. Figure 1 shows the schedule of the COURSE50, and Figure 2 shows its research and development organizations.

To develop technologies, a test blast furnace was built

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i http://www.kantei.go.jp/jp/abespeech/2007/05/24speech.html

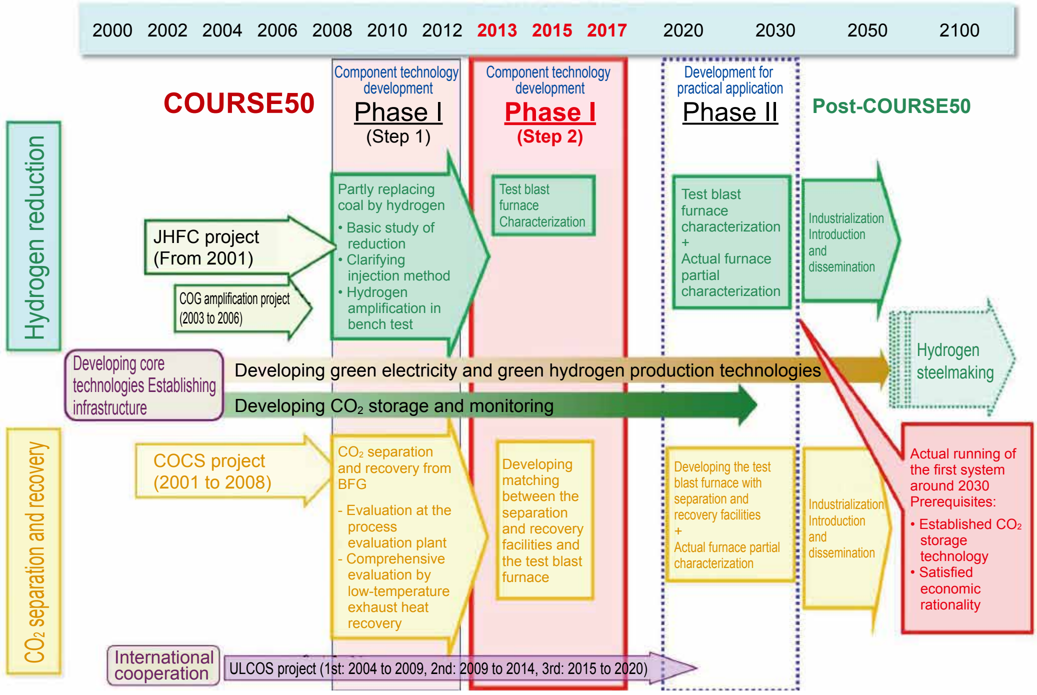

Figure 1 COURSE50 schedule

for the first time in 25 years in Japan. With the help of Nippon Steel & Sumikin Engineering, Yokogawa developed an analyzer system for measuring gas components, which indicate the normal operation of the test blast furnace as well as the effectiveness of new technologies. The analyzer system has been delivered to the test site and on-site engineering is now underway.

This paper outlines the measurements in the test blast furnace and introduces the analyzer system based on the GC8000 gas chromatograph.

PRESENT BLAST FURNACE PROCESS AND COURSE50 TECHNOLOGIES

For this project, Yokogawa has delivered a process analyzer for measuring the gas compositions at the shaft and top of the test blast furnace. The COURSE50 aims to develop technologies in two categories: "technologies to reduce CO_2 emissions" and "technologies to capture, separate and recover CO_2" [3]. Yokogawa's analyzer system plays an important role in indicating the status of achievement in the former category. Figure 3 shows the present blast furnace process and technologies to be developed in the COURSE50.

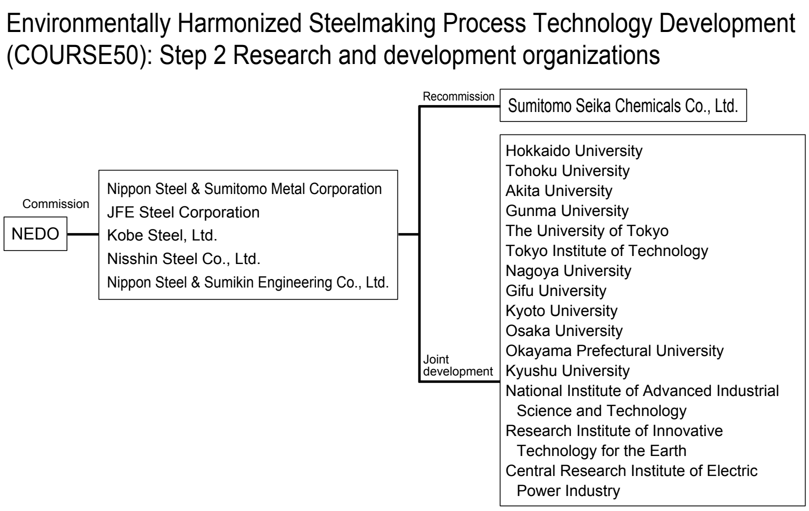

Figure 2 Research and development organizations

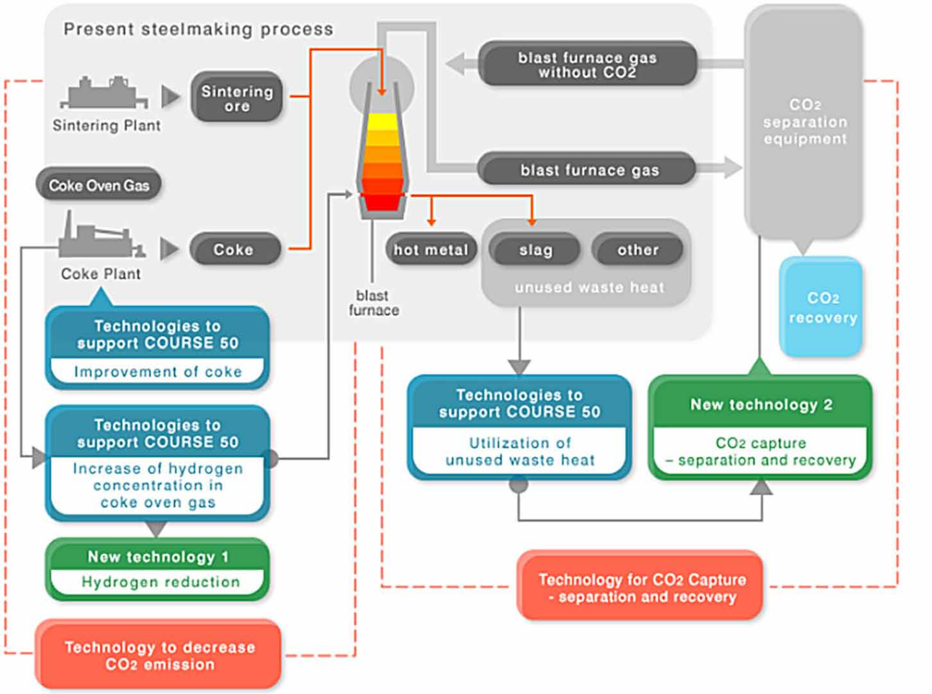

Figure 3 Present steelmaking process and technologies to be developed in the COURSE50

OUTLINE OF MEASUREMENT IN THE TEST BLAST FURNACE

Yokogawa's analyzer system is characterized by three horizontal probes which enable it to sample gases, measure temperature, and analyze gas compositions at the upper, middle, and lower parts of the furnace.

This system can measure gas components at 37 points in total: 1 point at the furnace top, and 36 points along the shaft (12 points each for the upper, middle, and lower horizontal probes). Figure 4 shows the locations of measuring gas components.

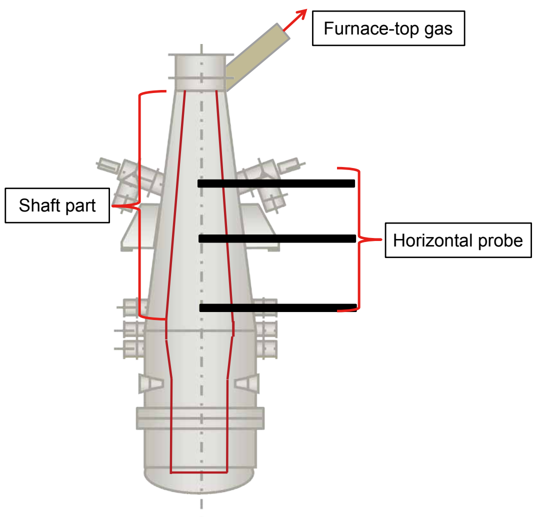

Figure 4 Locations of measuring gas components

OUTLINE OF THE GC8000 ANALYZER

Yokogawa's GC8000 gas chromatograph is used for the analyzer of the blast furnace gas measurement system since it can measure multiple components simultaneously. Thanks to its large touchscreen color LCD panel, the GC8000 is easy to use even in dark places. The GC8000 also features high reliability because it is designed for each measurement specification.

This system uses two GC8000 units: one for measuring the furnace shaft and the other for the furnace top. Since sample gas at each measurement point is an inorganic gas mixture with the same components including H_2, thermal conductivity detectors (TCD) and He carrier gas are used for all measurement points. As described below, however, there are differences in measurement methods and conditions, therefore fewer samples are collected over longer analysis cycles at the shaft than at the furnace top.

Continuous measurement analyzers are usually used to obtain management indices for manufacturing processes, and the GC8000 keeps measuring at the furnace top until the stop command is issued. In contrast, shaft measurements are carried out at arbitrary times. This is because the shaft of the furnace is at high temperature and contains raw materials such as sintered ore and coke as well as dust, and when sampling, various instruments are operated and a large amount of N_2 gas is consumed. To reduce the consumption of electricity and gas, measurement is carried out in batch mode at arbitrary times.

The two GC8000 units work with the measurement systems described below to measure multiple components simultaneously.

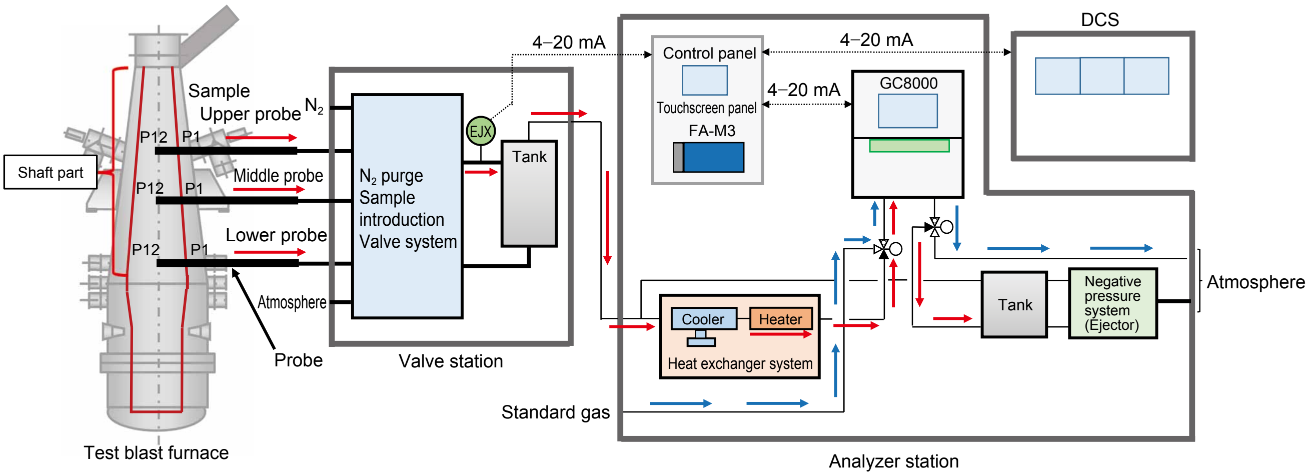

Figure 5 Flow chart of the shaft measurement system

SHAFT MEASUREMENT SYSTEM

The main component of the shaft measurement system is three horizontal probes. Figure 5 shows the flow chart of the system. Tables 1, 2, and 3 show the component devices and their features, the measurement system and its functions, and the functions of stations, respectively. Figure 6 shows an external view of the stations.

Table 1 Component devices of the shaft measurement system and their features

System	Component device	Features
Horizontal probe	Probe	With thermometer
	Probe drive unit	Drives the probe by pneumatic pressure
	Valve station	With pressure transmitter (EJX) and tank (with filter)
	Analyzer station	With GC8000, control panel (touchscreen panel and FA-M3), tank, ejector, heater, cooler
	DCS	Processes various measurement commands and input signals including analyzer data

Table 2 Outline of the measurement system and its functions

Horizontal probe	Outline	Collects sample gases through the probes located at the upper, middle, and lower parts of the shaft of the test blast furnace, and measures the pressure and temperature at each point. Stabilizes properties of the sample (temperature, pressure, water amount, and dust amount), sends the sample to the analyzer, separates its components, and measures the concentration of each gas component.
	Functions	Measures the horizontal distribution of gas composition, pressure, and temperature in the furnace shaft, and quantifies the conditions of the test blast furnace. The quantified conditions enable efficient feeding of raw materials and production of high-quality pig iron.

Table 3 Functions of stations

Station	Functions
Valve station	This station has a tank to store samples temporarily and stabilize properties of the sample. This station also has a function of N_2 purging.
Analyzer station	This station has an analyzer and negative pressure mechanism. Stabilizes samples further and sends them to the analyzer. This station also has a function of N_2 purging.

Figure 6 External view of stations

Two features of this measurement system are described below: the touchscreen panel, and the range-switching function.

Figure 7 shows the touchscreen panel of the shaft measurement system. Instead of traditional buttons and lamp indicators, the touchscreen panel is used for status confirmation, information display, and operation. This feature enables flexible response to changes in specifications, which are inevitable when developing a test blast furnace. The panel has windows dedicated for monitoring, status, operation, abnormality, and maintenance. Since related information is collectively displayed in each window, it is easy to check measurement points, operation processes, progress, time, and abnormalities. Various time settings can be easily changed, and operability and visibility in dark places have been improved.

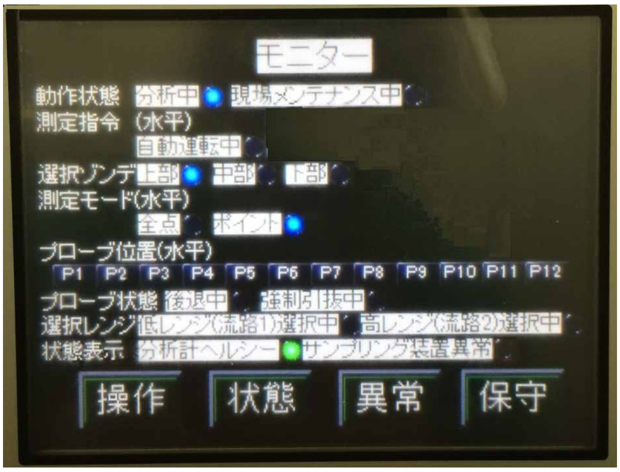

Figure 7 Touchscreen panel of the shaft measurement system (Japanese version only)

The shaft measurement system is also the first system with a range-switching function. When a blast furnace operates in normal conditions, measurement values change only slightly and stay within the normal range. In contrast, test blast furnaces are designed to be operated in various conditions, and thus the conventional H_2 range for blast furnaces may be insufficient for accurate measurement. Therefore, this analyzer system has two H_2 ranges, high and low, which can be selected from the control panel or DCS. An effectiveness confirmation function checks the adequacy of a range at each analysis cycle, which enables accurate measurement without being affected by changes in the amount of hydrogen contained in samples.

The major component of the shaft measurement system is described below.

HORIZONTAL PROBE MEASUREMENT SYSTEM

In the horizontal probe measurement system, the start command from the DCS triggers the devices in Table 1 to work together, and the analyzer carries out measurement in the order of processes (1) through (6) in Table 4.

There are two modes for the horizontal probe measurement, which can be selected by the DCS. One is a single point measurement mode in which measurement is carried out at only one point among 12 measurement points of the upper, middle, or lower probes, and the other is the all-point measurement mode in which measurement is carried out at all 12 measurement points sequentially.

Table 4 shows the actions of each device in the horizontal probe measurement. Repeating the actions in this table confirmed that each gas component can be measured at each time point, and that the concentrations vary over time and form trends. This result shows that the horizontal probe measurement system can effectively measure the concentrations of gas components at each sampling point for each sampling cycle, in the two measurement modes.

OUTLINE OF THE FURNACE-TOP MEASUREMENT

The furnace-top measurement system collects samples from the blast furnace gas dust removing system of the test blast furnace. Table 5 shows the component devices of the furnace-top measurement system.

Table 4 Actions of each device in the processes of horizontal probe measurement

<table>
<tr><td colspan="2" rowspan="2">Device</td><td colspan="2" rowspan="2">Valve station</td><td colspan="2" rowspan="2">Analyzer station</td><td colspan="2" rowspan="2">Probe</td><td colspan="4">GC8000</td></tr>
<tr><td colspan="2">Action</td><td colspan="2">Status</td></tr>
<tr><td colspan="2">Mode</td><td>All</td><td>Single</td><td>All</td><td>Single</td><td>All</td><td>Single</td><td>All</td><td>Single</td><td>All</td><td>Single</td></tr>
<tr><td rowspan="10">Process</td><td>(1)</td><td colspan="2">N_2 purge</td><td colspan="2" rowspan="4">Tank negative pressure</td><td colspan="2">Move</td><td colspan="2">—</td><td colspan="2">Stop</td></tr>
<tr><td rowspan="3">(2)</td><td colspan="2">Sample introduction</td><td colspan="2" rowspan="7">Measurement point</td><td colspan="2" rowspan="5">Preparation time</td><td colspan="2" rowspan="7">Run</td></tr>
<tr><td colspan="2">Pressure measurement</td></tr>
<tr><td colspan="2">Pressure stabilization</td></tr>
<tr><td rowspan="2">(3)</td><td colspan="2" rowspan="2">Sample discharge</td><td colspan="2">Sample replacement</td></tr>
<tr><td colspan="2">Sample transportation</td></tr>
<tr><td>(4)</td><td colspan="2">Waiting for measurement</td><td colspan="2">Atmospheric pressure equilibrium</td><td colspan="2" rowspan="2">Analysis cycle</td></tr>
<tr><td>(5)</td><td colspan="2">Filter backwashing</td><td colspan="2">Piping purge</td></tr>
<tr><td>(6)</td><td colspan="2">N_2 purge</td><td>Tank negative pressure</td><td>—</td><td>Forward</td><td>Backward</td><td>Analysis cycle</td><td>Analysis cycle</td><td>Run</td><td>Stop</td></tr>
<tr><td>—</td><td>Continue</td><td>End</td><td>Continue</td><td>End</td><td>Continue</td><td>End</td><td>Continue</td><td>End</td><td>Continue</td><td>End</td></tr>
</table>

* For the all-point measurement mode, repeat (2) through (6) until the measurement is completed for all measurement points.

Table 5 Component devices of the furnace-top measurement system and their features

Component device	Features
Sample probe	Collects samples. Removes dust to protect subsequent devices and piping.
First sampler	Purges N_2 to prevent clogging in the probes and piping. Switches the two samplers.
Second sampler	Stabilizes the sample flow rate and pressure to make the sample conditions measurable by the analyzer.
GC8000 analyzer	See "OUTLINE OF THE GC8000 ANALYZER."

Following the start command from the DCS, the furnace-top measurement system starts sampling. Since this system contains sampling gases with many impurities, it has two samplers to improve maintenance efficiency and ensure stable, continuous measurement. The command from the DCS or the touchscreen panel switches samplers in the next analysis cycle. When the samplers of general blast furnaces are switched, purging is carried out intermittently to prevent clogging in the unused line; N_2 purging is carried out manually in this test blast furnace. Figure 8 shows the touchscreen panel of the furnace-top measurement system. The layout is similar to that of the shaft measurement system, and the selected sampler and the N_2 purge can be easily confirmed.

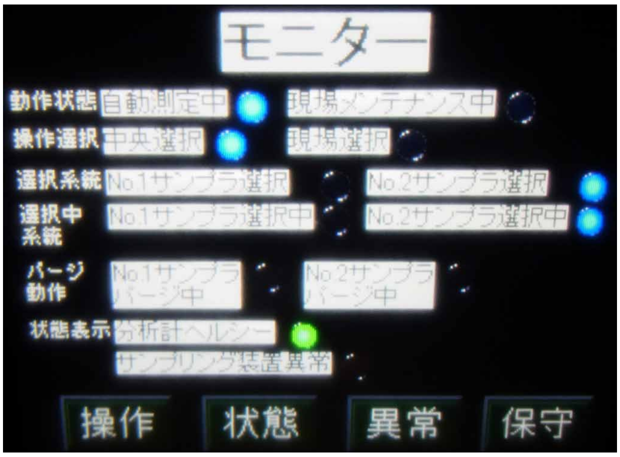

Figure 8 Touchscreen panel of the furnace-top measurement system (Japanese version only)

CONCLUSION

This paper introduced the COURSE50 project, an outline of the test blast furnace measurements in the project, and the GC8000 shaft probe analysis system that enables, for the first time in the world, gases to be measured at the three locations of upper, middle, and lower parts in the test blast furnace.

Yokogawa has a solid track record in the field of process gas chromatograph over 50 years both in and outside Japan, and also in analyzer systems in various plants. Indices obtained by the measurement are not only indicators of the operation and efficiency of customer plants, but are also crucial factors leading to solutions to environmental issues.

Yokogawa will help customers create new value and improve the environment, by jointly developing system solutions such as the analyzer system described in this paper.

This study was carried out as part of the "Environmentally Harmonized Steelmaking Process Technology Development" project commissioned by the New Energy and Industrial Technology Development Organization. The author sincerely thanks all those concerned.

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