DEVELOPMENT OF HITACHI OXY-COMBUSTION TECHNOLOGY WITH NEW TYPES OF BURNER AND FLUE GAS RE-CIRCULATION SYSTEM

Takahiro Marumoto[1]*, Noriyuki Imada [1]*, Kenji Kiyama [2]**,
Pauli Dernjatin [3]****, Song Wu [4]*****
*1 Babcock-Hitachi K.K. Kure Research Laboratory
Takara-machi 5-3, Kure, Hiroshima, Japan 737-0029
**2 Babcock-Hitachi K.K. Kure Division
Takara-machi 6-9, Kure, Hiroshima, Japan 737-8508
***3 Fortum Corporation
Keilanimentie 1, Espoo, Finland
****4 Hitachi Power Systems America, Ltd
645 Martinsville Road, Basking Ridge, NJ 07920, USA

POWER-GEN International, December 14-16, 2010, Orlando, FL

ABSTRACT

Hitachi has developed an advanced oxy-combustion system for coal-fired power plants. The system is simple, reliable and highly efficient, and uses a new burner design that can achieve stable operation over a wide range of conditions. As a part of the development effort for the oxy-combustion system, Babcock-Hitachi K.K. (BHK) and FORTUM have jointly studied a conceptual oxy-combustion power plant design that allows practical carbon dioxide (CO_2) capture for future CO_2 sequestration efforts.

Hitachi has its original technology for sulfur trioxide (SO_3) removal, which consists of a low-temperature gas cooler and a dry ESP (electrostatic precipitator). This technology has been applied to the oxy-combustion system for removing SO_3, recover flue gas heat, and to prevent acid corrosion in the flue gas recirculation lines back to mills.

The Hitachi NR-LE burner, originally developed for firing lignite, was used for the oxy-combustion system to achieve stable combustion under the low O_2 content of primary gas. Stability of the NR-LE burner was confirmed by combustion tests using a 4MWth test facility.

1. INTRODUCTION

Increasing energy efficiency, utilizing low carbon fuels, and carbon sequestration are the key pathways toward reduction of greenhouse gas emissions. Carbon captures and sequestration from power plants is important since a substantial portion of greenhouse gas emissions in the world are from power generation sources, especially coal-fired power plants. Hitachi has been developing two key technologies of CO_2 capture from coal-fired power plants (Fig.1): CO_2 scrubbing and oxy-combustion. Oxy-combustion is an effective method in that it can remove all CO_2 from combustion flue gas. The oxy-combustion system can be retrofitted to existing power plants with no change to the plant water-steam cycle and only limited modifications to the boiler. This is important since coal fired power plants are currently the leading source of power generation in the world.

As a part of the development program, BHK and FORTUM have jointly studied a conceptual oxy-combustion power plant design that allows practical carbon dioxide (CO_2) capture for future CO_2 sequestration efforts. The study includes a feasibility study for retrofitting existing power plants with oxy-combustion and combustion tests using a 4.0 MWth horizontal furnace with a single burner[1)-4)].

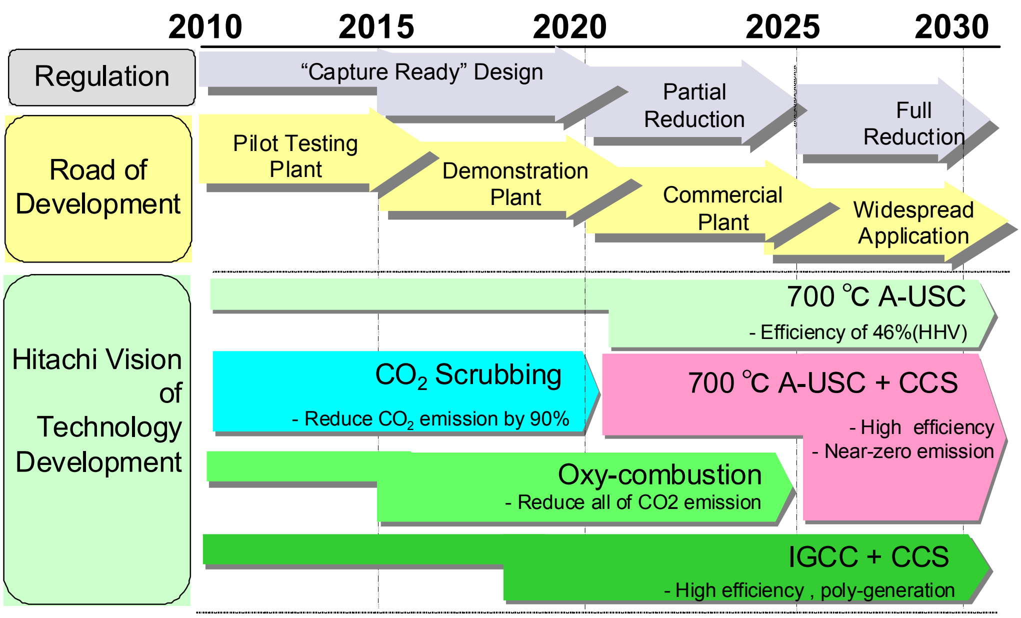

Fig.1 Hitachi CCS Roadmap

In oxy-combustion system, mercury in the flue gas may cause corrosion in CO_2 purification and compression units. Therefore, Hitachi conducted tests using a 1.5MWth Combustion & AQCS (Air Quality Control System) test facility which consists of oxygen supply unit, furnace, SCR, heat exchanger, ESP, flue gas recirculation system and Wet-FGD. This study was partly carried out under contract with New Energy and Industrial Technology Department Organization (NEDO) of Japan.

2. HITACHI ORIGINAL OXY-COMBUSTION SYSTEM

Hitachi has developed a new system for oxy-combustion (Fig.2) that is reliable and highly efficient. Features of this system include:

(1) Stable combustion under low O_2 content of primary gas is with a new burner (Hitachi patented NR-LE* burner).

(2) SO_3 removal by decreasing temperature of flue gas at ESP inlet with Hitachi's patented cooler system.

(3) A large increase of LP turbine power (18MW for a 500MW unit) because the Hitachi gas cooler preheats boiler feed water and reduces steam extraction from LP turbine.

(4) Improvement of plant net efficiency of 2.0 percentage points. (Table1)

*: NOx reduction and load extension burner

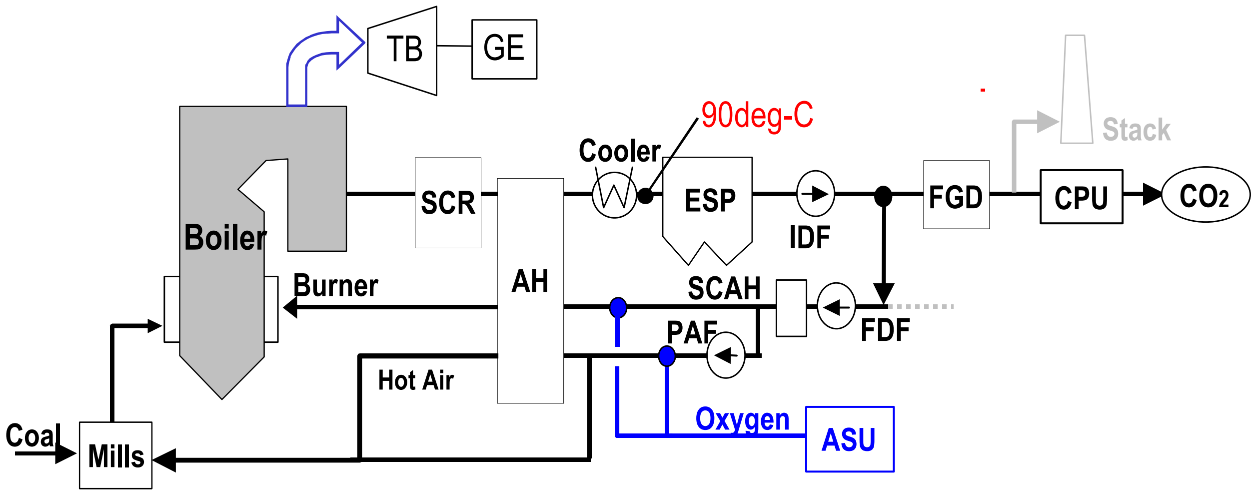

Fig.2 System flow of a Hitachi original oxy-combustion

Table1 Improvement of plant efficiency by Hitachi oxy-combustion system

Item	Improvement of plant efficiency[point]
Heat recovery of gas cooler	1.5
O_2 Inject upstream of gas heater	0.5
Total	2.0

2.1 Concept of Hitachi NR-LE burner

Figure 3 shows configuration of Hitachi NR-LE burner. The NR-LE burner was originally developed for lignite coal combustion. To achieve stable combustion under oxy-fuel conditions, the NR-LE burner was designed with the following concept.

(1) O_2 concentration of primary gas is maintained at 21vol%-wet or less.

(2) To promote the ignition of the pulverized coal, secondary gas of a higher O_2 concentration is supplied to the pulverized coal concentrate area of primary gas line.

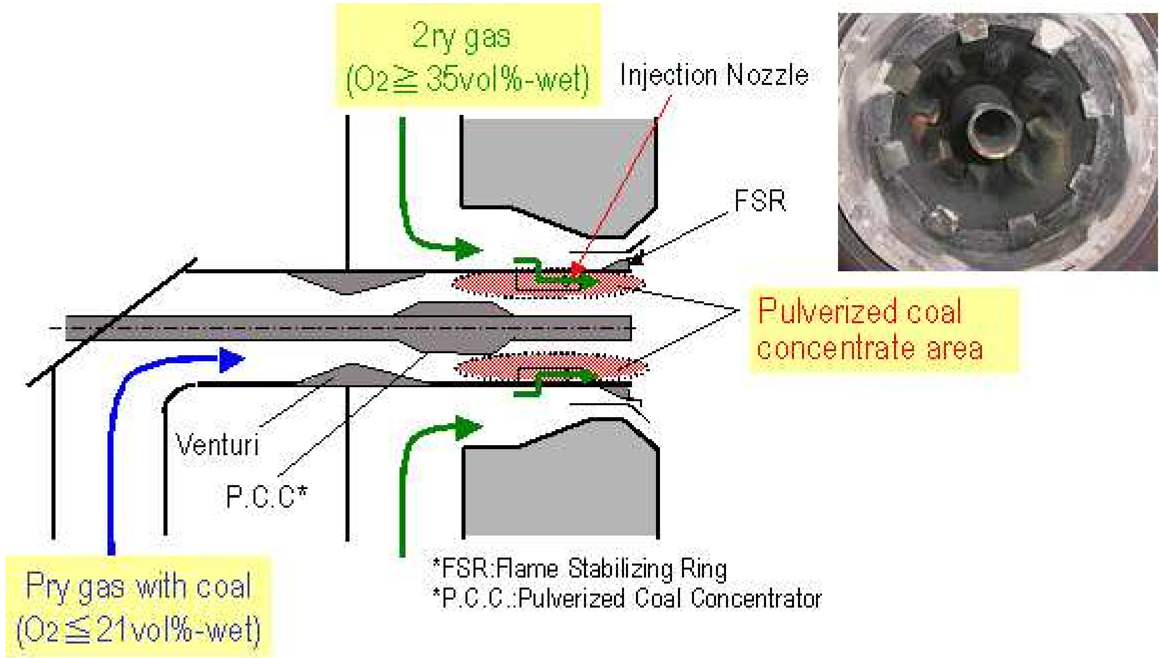

Fig.3 Configuration of Hitachi NR-LE burner

2.2 Mechanism of SO_3 reduction

BHK had developed an original SO_3 remove technology using the original gas cooler system before the BHK & Fortum joint study and has applied the technology for the feasibility study of retrofitting existing power plants with oxy-combustion.

At the flue gas temperature below acid dew point, SO_3 gas contained in flue gas changes to mist (liquid) and sticks to coal ash particles which are caught by the ESP. SO_3 mist is neutralized by alkali contained in ash, so that corrosion of ESP material is prevented. (Fig.4)

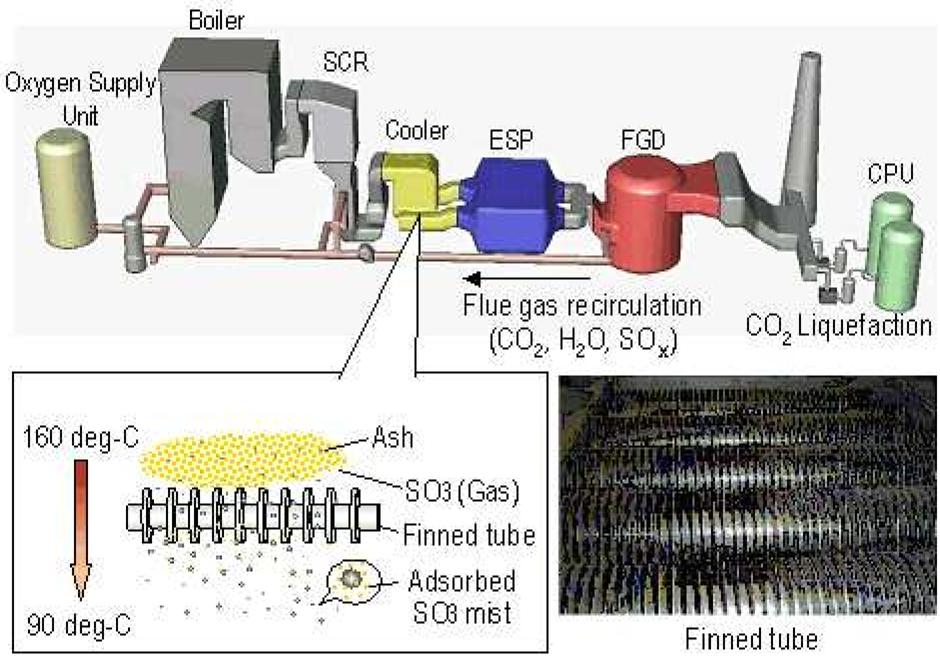

Fig.4 Mechanism of SO3 removal with cooler system

3. EXPERIMENTAL APPARATUS

3.1 4 MWth test facility for burner verification

Figure 5 shows a three-dimensional view of the 4MWth combustion test facility. This facility consists of a horizontal furnace and a single burner. The maximum combustion capacity is 500 kg/h of coal. Re-circulated flue gas was taken from the duct downstream of the spray tower using a GRF (Gas Recirculation Fan) and injected at the burner and the AAP (After Air Port). Oxygen gas was supplied to both the burner and the AAP lines, and their flow rates were measured by flow meters individually.

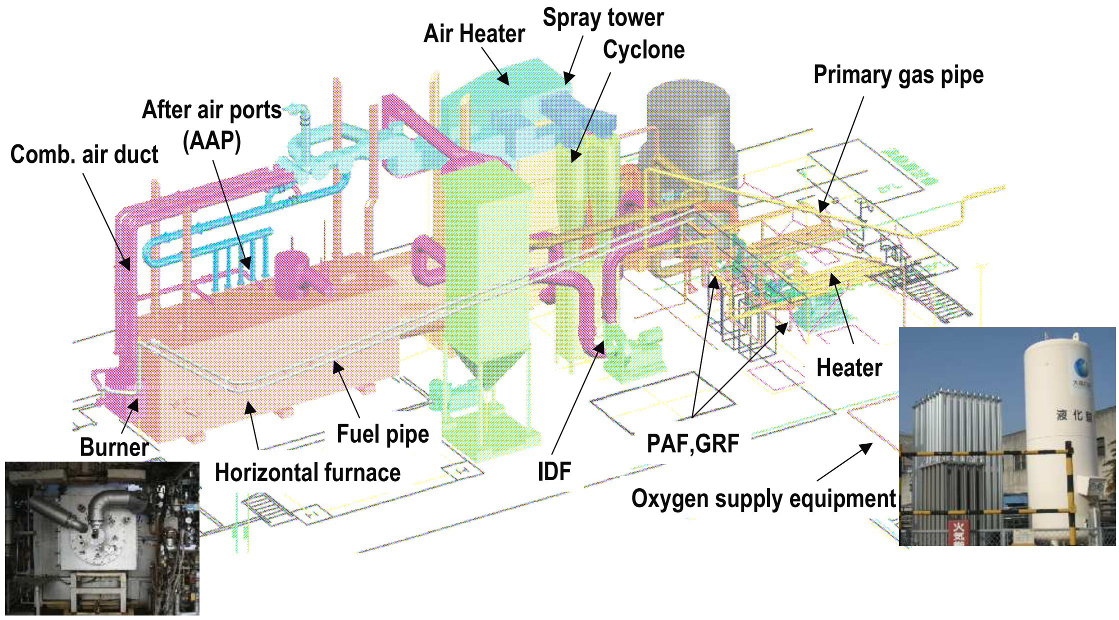

Fig.5 Three-dimensional view of 4MWth combustion test facility

3.2 1.5 MWth test facility for evaluation of mercury behavior

In the oxy-combustion system, mercury in the flue gas may cause corrosion in CO_2 purification and compression units. Therefore, Hitachi conducted tests using a 1.5MWth Combustion & AQCS (Air Quality Control System) test facility (Fig.6), which consists of oxygen supply unit, furnace, SCR, heat exchanger, ESP, flue gas recirculation system and Wet-FGD. This study[5)] was partly carried out under contract with New Energy and Industrial Technology Department Organization (NEDO) of Japan.

Test results to date shown that under oxy-combustion; the mercury removal across the ESP is higher than that of air combustion. Installing a gas cooler upstream of ESP and reducing the gas temperature at the ESP can further improve the mercury removal efficiency[5)]. Now, we plan to test a coal with lower chlorine and higher sulfur.

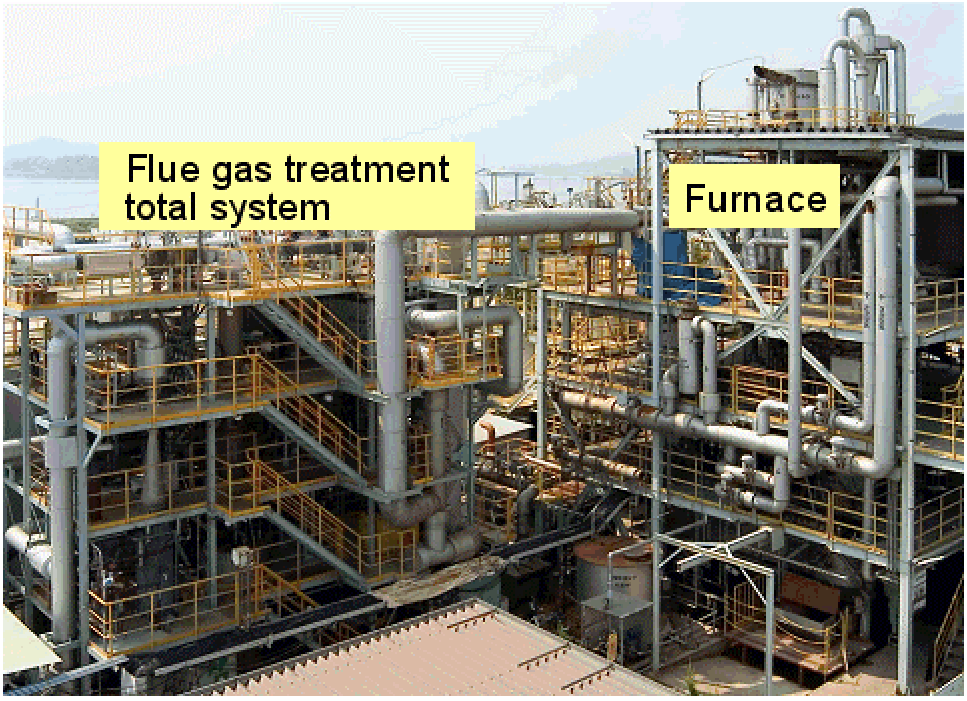

Fig.6 1.5MWth Combustion & AQCS test facility

4. RESULTS AND DISCUSSIONS

4.1 Flame stability of Hitachi NR-LE burner

For the Hitachi NR-3 burner, which was originally developed for bituminous and sub-bituminous applications, the minimum primary O_2 limitation for flame stability is about 21%-wet. For NR-LE burner, the primary O_2 concentration can be reduced to 10%-wet without any combustion problems such as flame stability and high levels of unburned carbon. (Fig.7)

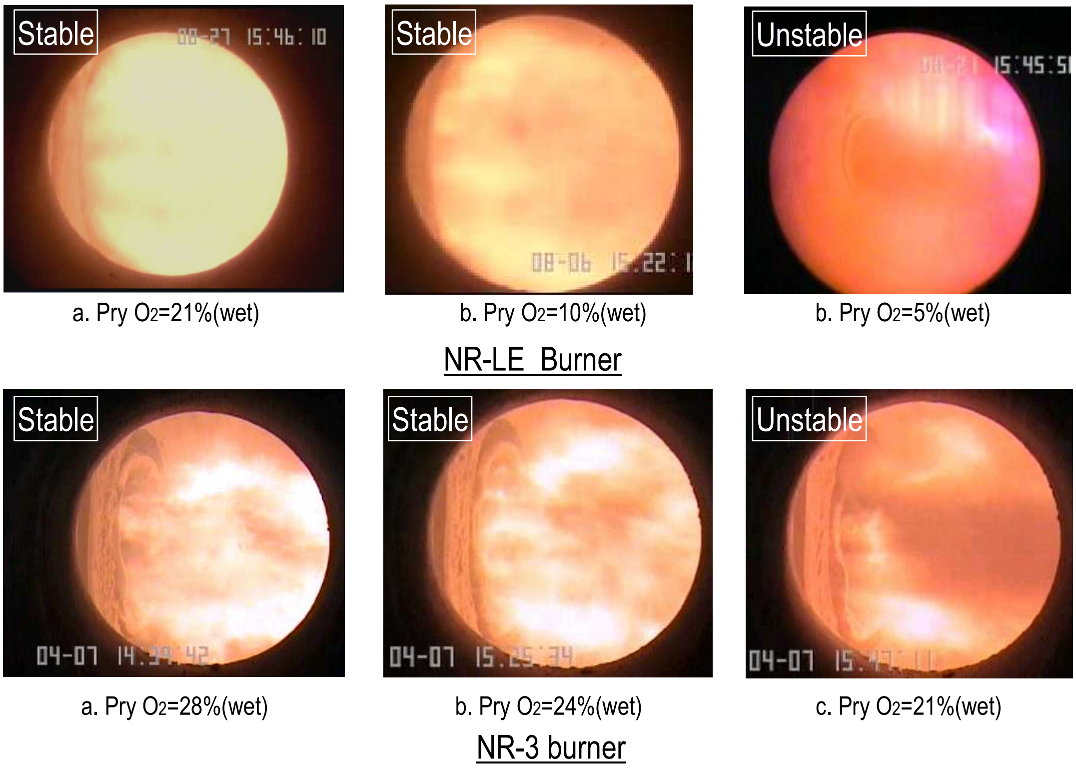

Fig.7 Flame Photographs of Hitachi NR-LE and NR-3 burner (Average O_2 28%-wet)

4.2 SO_3 reduction by the Hitachi gas cooler system

SO_3 concentration profiles in AQCS are shown in Fig.8. The gas cooler reduces SO_3 concentration to below 1ppm at the ESP Inlet. The value of 1ppm is enough to avoid acid corrosion of material of the flue gas and recirculation gas ducts.

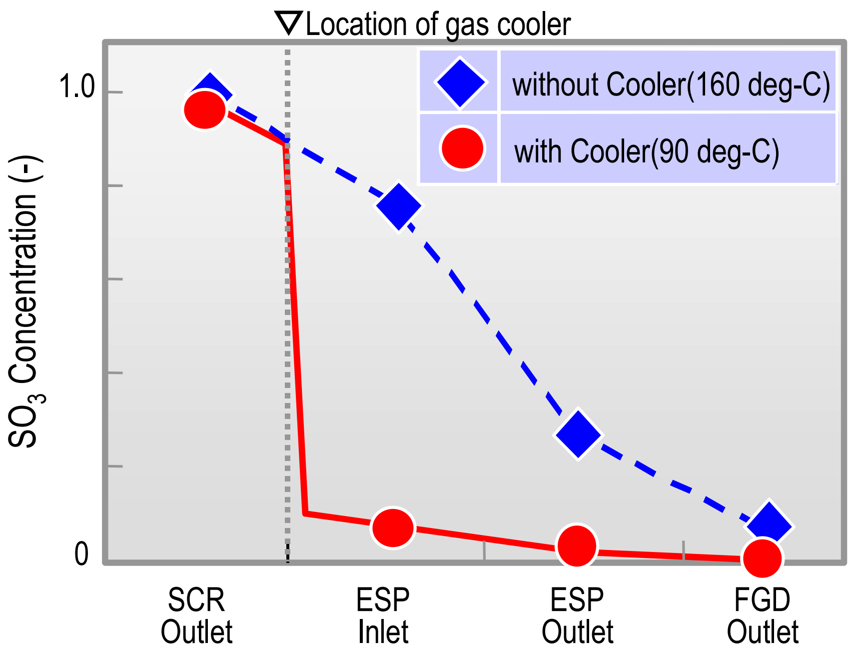

Fig.8 SO_3 concentration profiles in AQCS

4.3 Plant layout

Figure 9 shows the plant layout of a 500 MW class oxy-combustion power plant. The coal flow rate is about 150 t/h and flue gas flow rate is about 520 t/h.

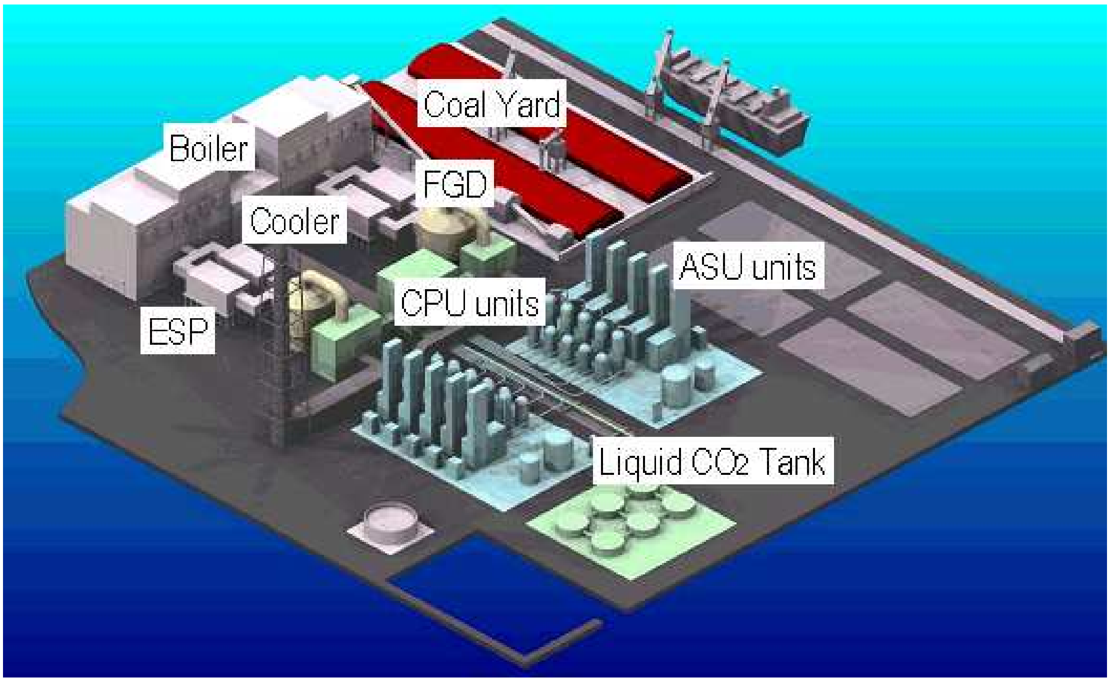

Fig.9 Plant layout of 500 MW class oxy-combustion power plant

4. SUMMARY

Hitachi has developed a new system for oxy-combustion that is reliable and highly efficient. Features of this system include:

(1) Stable combustion under low O_2 content of primary gas with the NR-LE burner.
(2) SO_3 removal by decreasing flue gas temperature at the ESP inlet with the Hitachi cooler system.
(3) A large increase in LP turbine power because the new gas cooler preheats boiler feed water and reduces steam extraction from LP turbine.
(4) Improvement of plant net efficiency of 2.0 percentage points.

Extensive development and demonstration programs are underway to support commercial implementation of this technology in the near future.

References

1. T. Marumoto et al., Feasibility Study on Oxy-Combustion Retrofit of an Existing Coal-Fired Power Plant, Power-Gen International 2009
2. T. Mine et al., Oxyfuel Combustion Properties based on Horizontal Single Burner Furnace Tests, 2009 International Pittsburgh Coal Conference
3. Y. Fukuda et al., Oxyfuel Retrofit to Coal Power Plant (Part1) – FS of 500MW Class Plant, IEA 1st Oxyfuel Combustion Conference, 2009
4. T. Mine et al., Oxyfuel Retrofit to Coal Power Plant (Part2) – Combustion Properties, IEA 1st Oxyfuel Combustion Conference, 2009
5. N. Imada et al., Study of Mercury Behavior in Flue Gas of Oxy-fuel Combustion, Proceedings of the Clearwater Clean Coal Conference, 2010
6. N. Imada et al., Development of Mercury and SO_3 Control Technology using Gas-Gas Heater, Proceedings of the Clearwater Clean Coal Conference, 2010