

Hitachi Latest Technologies for Coal Firing Power Plant

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Abstract

Hitachi has been developing the new technologies, not only for boiler equipment such as combustion systems but also for environmental control systems including SCR, dry electrostatic precipitator (ESP) and wet Flue Gas Desulfurization (FGD), as a whole plant supplier for thermal power plants. Now we at Hitachi can design and supply the latest power plant equipment with high efficiency and reliability.

Unique concept of the HT-NR Burner, "In-Flame NO_x reduction" has overcome the trade-off relationship between reducing NO_x and increasing unburned material. The performance of the HT-NR Burner Series has been enhanced step by step by upgrading the key devices, and extremely low NO_x combustion with high efficiency has been realized by the latest model together with the advanced two stage combustion system.

Hitachi's advanced mercury oxidation TRAC[®] catalyst has extensive durability and after field demonstrations in the U.S, TRAC[®] has been commercially utilized since 2007 with full mercury oxidation guarantees.

We at Hitachi can offer the latest Hitachi Air Quality Control System (AQCS) equipped with TRAC to enhance removal efficiency of trace elements such as mercury and SO₃ where the heat exchanger is a key component for cleaning coal fired flue gas to meet the stringent regulations.

1. Introduction

Recently, the owners for thermal power plants have been required to operate their plants with more competitive and reliable technologies to keep their high efficiency. On the other hand, the utilities especially with coal fired power plants will soon have to comply with new regulations getting more stringent such as MATS (Mercury and Air Toxics Standards) regulation in the U.S which focuses on mercury and other hazardous pollutants for coal firing plants. In addition, Environmental Protection Agency (EPA) in the U.S. also issued the regulation for Green House Gas (GHG) for combustion furnace on 25, March, 2012. According to the GHG regulation issued, new coal firing power plants have to capture CO₂ except for the projects which are under construction and designing.

Hitachi, is one of the boiler manufacturers and environmental control system suppliers, had been developing new technologies for power plants including boiler, SCR, AQCS, amine-based scrubbing, oxy-fuel combustion, IGCC with CO₂ absorption, and 700°C class advanced ultra supercritical boiler-turbine system, to tackle the issue of global climate change.

2. Ultra Super Critical (USC) Plant

The recent global energy situation strongly requires environmental preservation and economical efficiency, therefore, the supercritical technologies for fossil power plants have become more important all over the world with their features of high efficiency, flexibility and high availability.

Figure 1 shows the improvement of heat rate due to turbine efficiency for various steam parameters, for subcritical and supercritical power plants. Under the same performance conditions (i.e. fuel properties, ambient temp, flue gas temp at air heater outlet, etc), there is no difference in the boiler efficiency between subcritical and supercritical steam conditions. The improvement in plant efficiency by using supercritical cycle results in fuel consumption savings and reduced flue gas emissions, especially CO₂ emissions can be reduced according to thermal efficiency improvements.

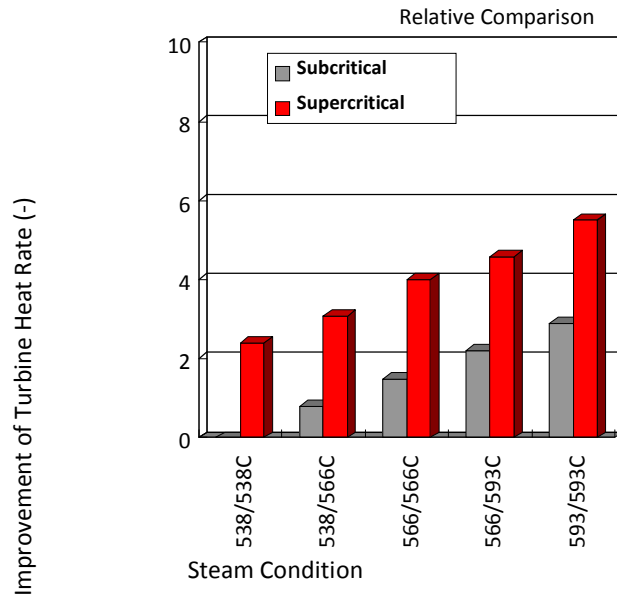


Figure 1 Supercritical vs. Sub critical Heat Rate Comparison

Babcock-Hitachi K.K. (BHK) has been developing steam condition as shown in Figure 2. In early 1990's, the turbine inlet steam condition of 24.1MPa/538C/538C was conventional condition. In subsequent plants, steam conditions were steadily increased in order to improve unit efficiency. Through gradual developments in boiler design, construction and materials, steam temperatures over 600°C have been successfully achieved as shown in Figure 2.

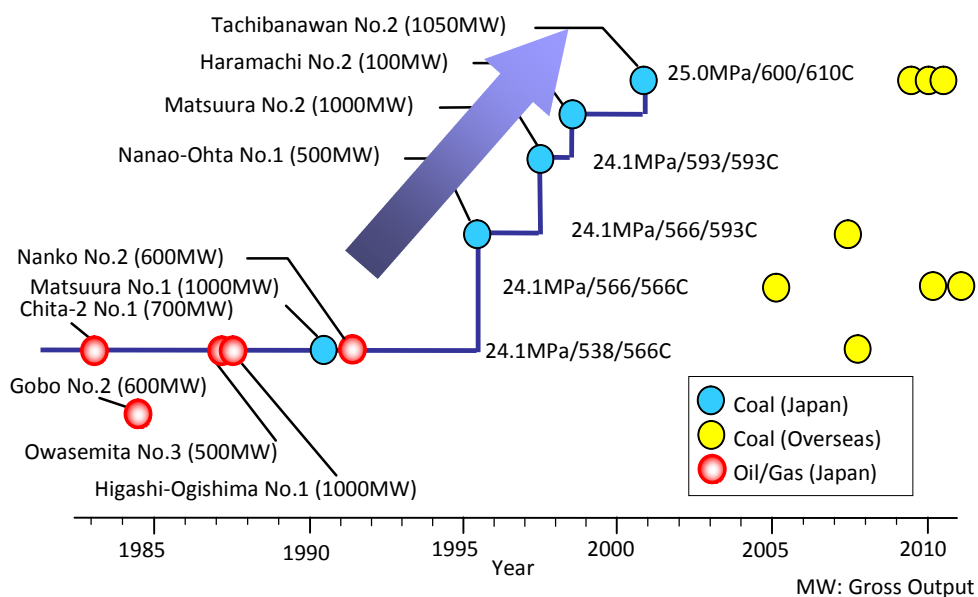


Figure 2 Improvement of Steam Conditions for Coal Fired Boilers by BHK

3. Advanced - Ultra Super Critical (A-USC) Plant

Recently years the environmental restrictions on CO₂ emission require advanced power plants with higher efficiency than the existing plants. These restrictions have prompted to adopt the fossil fired power plants with higher steam temperature and pressure conditions. The research and development on A-USC power plants with the steam conditions of 700°C or higher are ongoing in Europe, USA and Japan [1]. Recently China and India have also started the development. To achieve such advanced steam conditions, the application of high strength Ni based alloys such as well-known Alloy617, Alloy263 and Alloy740 becomes essential. In Japanese A-USC national project launched in 2008, Fe-Ni based alloy HR6W (45Ni-24Fe-23Cr-7W-Ti) is also one of the candidate materials for boiler tube and pipe as well as Ni based alloys.

Critical issues to be settled are the development of materials for boiler tube and thick-wall pipe as well as the establishment of the corresponding fabrication procedures. Since no experience is available for the manufacturing of Ni-based alloys as the actual boiler components, the establishment of practical fabrication procedures is still a challenging problem [2]. One of the most important issues of them is the establishment of appropriate welding process for the thick-wall components and the verification of long-term reliability of their weldments.

Previous studies [2] have indicated that the conventional welding procedures like submerged arc welding (SAW) and shield metal arc welding (SMAW), were probably not feasible for Ni based welding material due to the problems such as slag removal, oxidation loss of strengthening alloy elements (Al, Ti) during the welding, hot cracking sensitivity, and so on. Gas tungsten arc welding (GTAW) process is acceptable for small boiler tube, but it is difficult to apply for the welding of thick-wall components because of its relatively lower welding efficiency. Thus, the aim of the present work is to establish the proper welding technology for the thick-wall components of Ni or Fe-Ni based candidate materials for A-USC power plants.

Narrow gap HST (Hot wire Switching TIG) welding procedure, which was originally developed by BHK as one of the most advanced welding techniques of Babcock-Hitachi, is widely used for boiler header and piping made of high alloy steels in both of our workshop and at election site for several decades. Figure 3 gives the illustration of the schematic mechanics of narrow gap HST welding process. As shown in Figure 3, comparing with the conventional SAW and SMAW welding processes, one-pass-one-layer technology of narrow gap HST welding process with fewer weld layers and less deposited metal offers higher welding efficiency. Figure 4 shows the narrow gap welding applied to past USC boiler components [3].

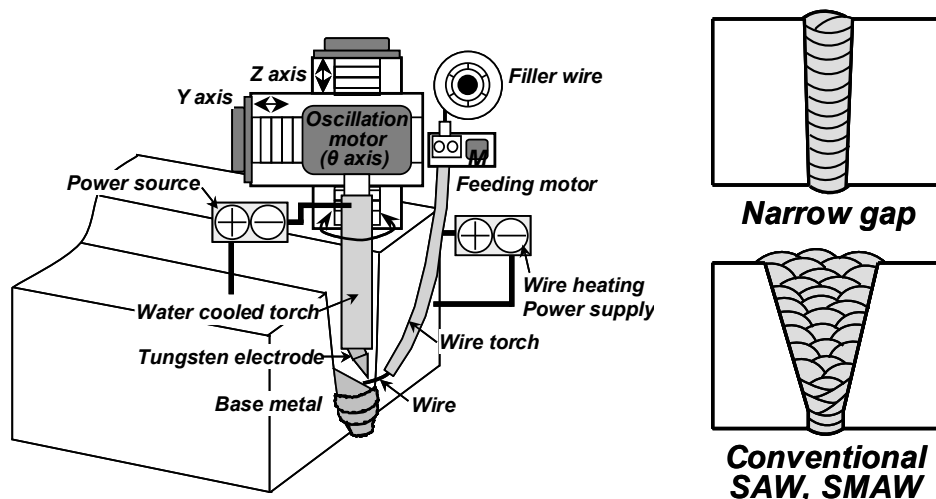


Figure 3 Schematic mechanics of narrow gap HST welding equipment and its advantage

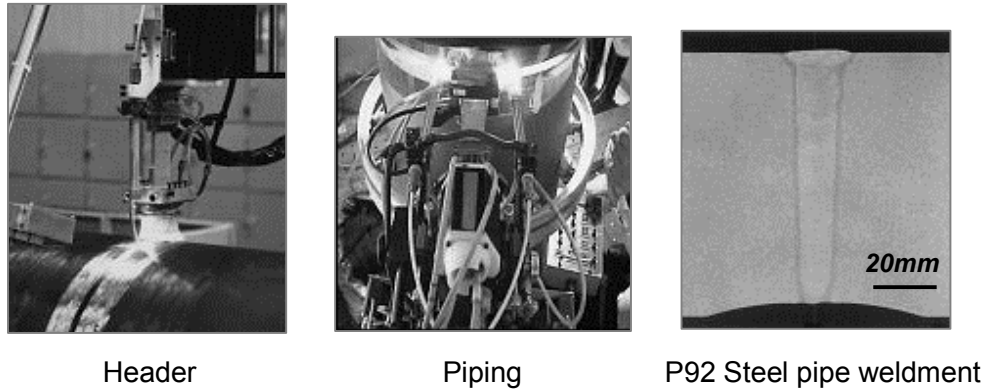


Figure 4 Narrow gap welding applied to USC boiler components

Welding trials on Fe-Ni based HR6W pipe were conducted by using the narrow gap HST welding procedure. The welding test was conducted successfully and Figure 5 shows the weldment. It was confirmed that there was no defects like crack, porosity or lack of fusion by non-destructive tests, bend tests of the weldment and metallurgical investigation. To confirm the long-term stability of the creep rupture strength, long-term creep rupture tests of weld joint are still ongoing (Figure 6). The Narrow gap HST welding is expected to be a preferable welding procedure for Fe-Ni and Ni based thick-wall pipes for A-USC boiler components.

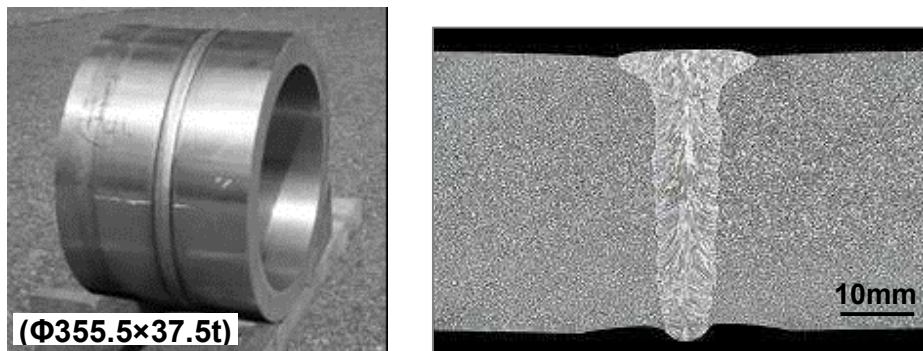


Figure 5 HR6W pipe weldment and its macro structure on the cross section

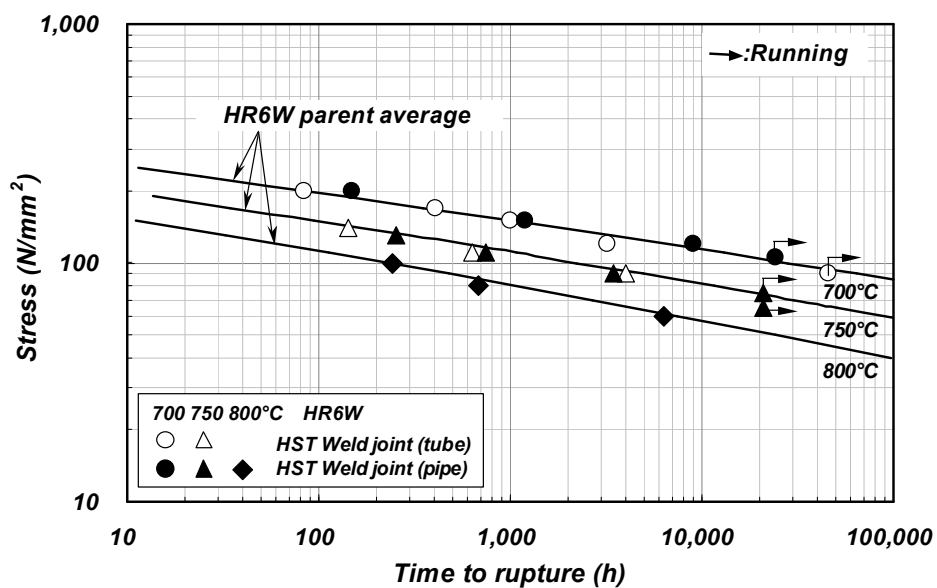


Figure 6 Creep rupture strength of HR6W HST weld joint

4. High efficient low NOx combustion technologies for coal fired unit

Coal fired power plants are major energy sources world' wide in view of their stable and economical energy supply. The environmental burden from coal fired power plants such as nitrogen oxide (NOx), sulfur oxide (SOx) and carbon dioxide (CO₂) is higher in terms of calorific values than oil or gas fired plants, hence reduction and preventive measures are prerequisites to the plants. BHK has been focusing on upgrading technologies to reduce the environmental burden.

NOx, a major environmental burden, can be reduced by improvement of combustion methods (low NOx combustion technologies), and NOx reduction has been realized through developments in burners and combustion methods in the furnace.

The HT-NR Burner Series has an unique combustion concept-"In-Flame NOx Reduction" [4] introduced for the first time by BHK, whereby NOx is reduced in the flame of the burner. In-Flame NOx Reduction is a technology, to which NOx reduction reaction under high temperatures and fuel-rich conditions just after ignition of pulverized coal is applied. The concept of In-Flame NOx Reduction is shown in Figure 7.

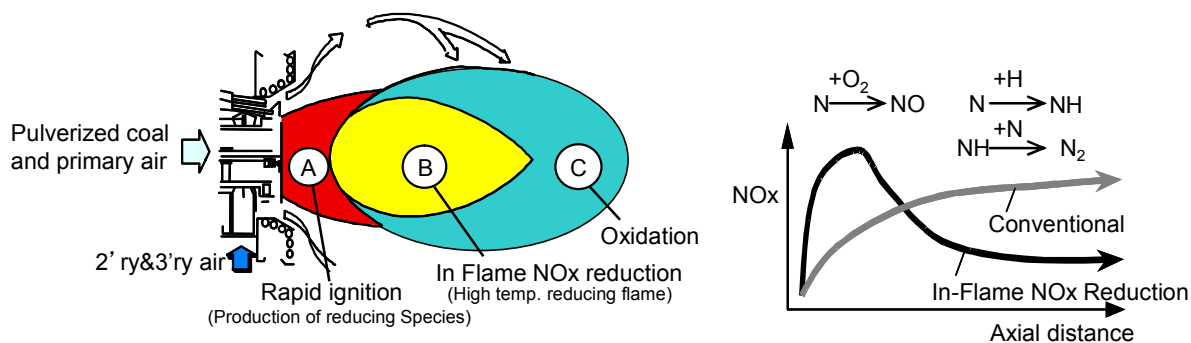


Figure 7 Concept of In-Flame NOx Reduction

The structure of HT-NR3 Burner, which has been widely applied in various area of the world in recent years, is shown in Figure 8. Features that realize extremely low NOx performance are described as follows;

(1) Expansion of recirculation zone after Flame Stabilizing Ring

A rapid ignition of pulverized coal just after the fuel nozzle exit is important to maintain stable flame for enhancement of In-Flame NOx Reduction. By establishing a flame at the early stages of combustion, consumption of oxygen is promoted and a NOx reduction zone under low oxygen conditions is expanded. In HT-NR3 Burners, the recirculation zone formed after the fuel nozzle is expanded by changing the direction of secondary air jets to the outside along the Baffle Plate, which is equipped on the Flame Stabilizing Ring. As hot gas stagnates in the recirculation zone, pulverized coal is rapidly heated and this enhances ignition.

(2) Concentration of pulverized coal

Concentration of pulverized coal is pivotal to ignition enhancement. The denser the pulverized coal, the shorter distance among coal particles. This is advantageous for rapid ignition and flame stability due to better flame propagation. The Pulverized Coal Concentrator (PC Concentrator) has the shape of an artillery shell and is installed in the fuel nozzle of the HT-NR3 Burner. Combining pulverized coal and primary air simultaneously tend to move close to the inner wall of the fuel nozzle at the parallel part of the PC Concentrator, whereby only air returns to the center zone utilizing the difference in momentum between pulverized coal and air at the exit of the fuel nozzle. As the result, pulverized coal is concentrated around the Flame Stabilizing Ring equipped at the exit of the fuel nozzle.

(3) Optimum flow pattern of outer air

Tertiary air expands to the outside at the burner exit, and reducing zone under fuel rich conditions formed in the center zone of the flame. Tertiary air returns to the center of the flame after completion of NO_x reduction reaction, and mixes with the flame for promotion of combustion. In HT-NR3 Burners, a simple Guide Sleeve effectively separates this reaction from outer air.

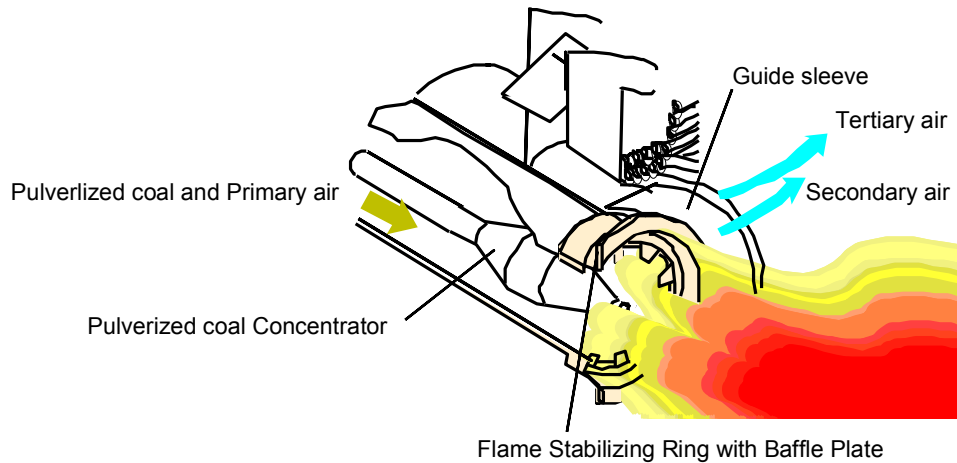


Figure 8 Structure of NR3 Burner

The application of a Two Stage Combustion (TSC) through the burners further reduces NO_x. In this method, a combustion reaction of NO_x decomposition under air lean conditions is promoted between the burners and the TSC ports, after that combustion of unburned material is completed between the TSC ports and the furnace exit.

It is well known that NO_x reduction is enhanced by enlarging the distance (H_R) between burners and TSC ports. On the other hand, enlarging H_R under the same furnace height brings shorter distance between the TSC ports and the furnace exit, and combustion efficiency is lowered due to higher CO and unburned carbon (UBC). This trade-off relationship between NO_x and CO/UBC is a challenge to be resolved.

To overcome this trade-off, BHK has developed advanced multi stage TSC ports, and succeeded in promoting a combining between TSC air and unburned gas. This new technology enables CO reduction within a shorter distance. Even in the case where NO_x is reduced by enlarging the reducing zone, an increase of CO can be prevented. By the development of this advanced combustion method, a simultaneous reduction of both NO_x and CO is realized. Comparison of concepts between conventional and advanced combustion methods is shown in Figure 9.

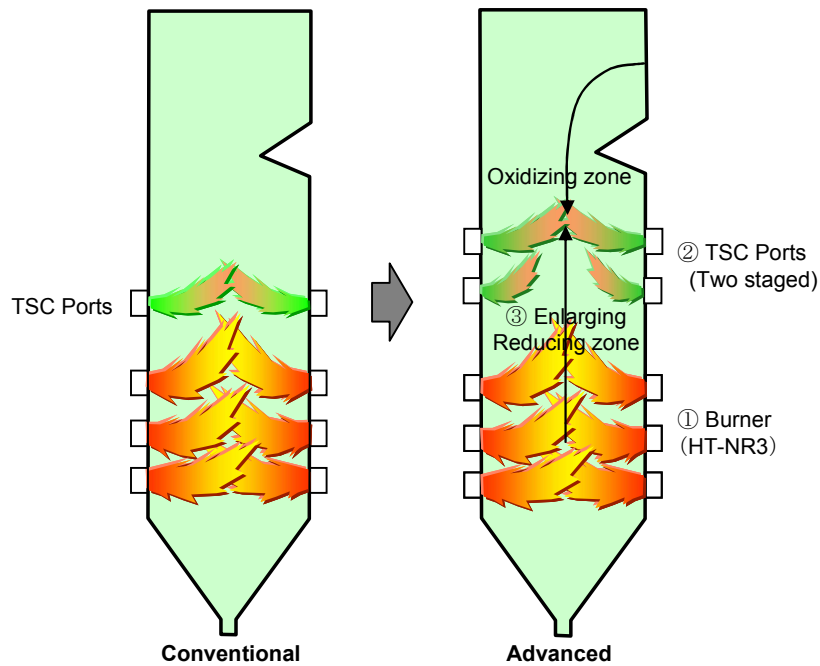


Figure 9 Concept of Advanced TSC System

The HT-NR4 Burner is the latest model of the HT-NR Burner Series. Basic concept of the HT-NR4 Burner is the same as the HT-NR3 Burner, however, the shape of the fuel nozzle has been changed to planular from circular. This change of the shape is advantageous for better mixing of fuel and air in the furnace and consequently higher combustion efficiency keeping low NO_x performance. As the combination of the HT-NR4 Burner and the advanced TSC system, NO_x has been dramatically reduced as shown in Figure 10.

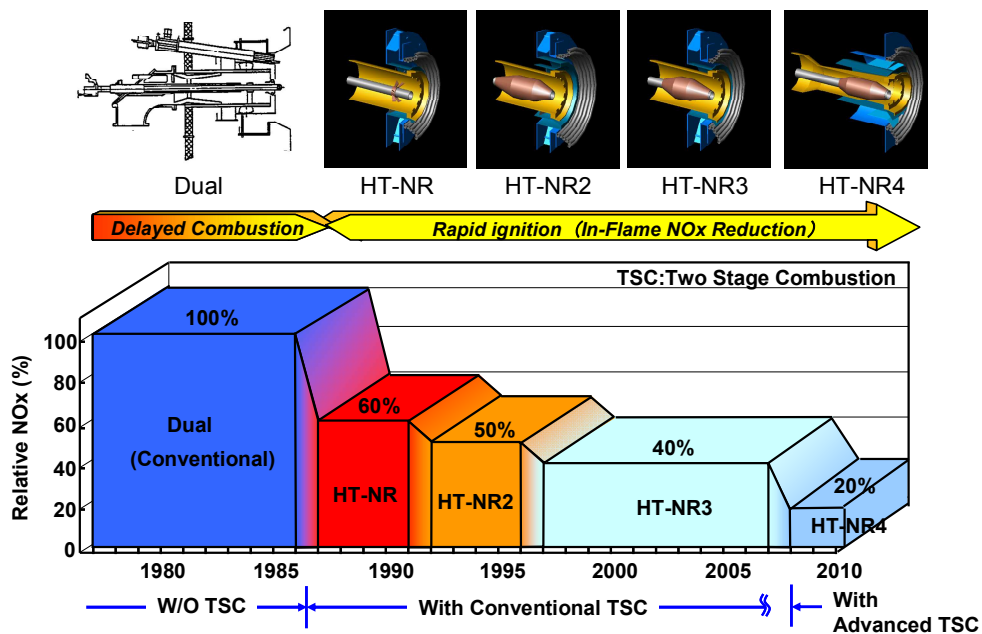


Figure 10 History of NO_x Performance of the HT-NR Burner Series

5. AQCS

In the U.S., utilities with coal fired power plants will soon have to comply with the new MATS (Mercury and Air Toxics Standards) regulation which focuses on mercury and other hazardous pollutants and then the owners for coal fired units have to meet the regulation by 2015. Now, more than ever, Utilities are searching for the most economical path to comply with environmental regulations [5]. Hitachi has developed a new AQCS to meet the stringent emission regulation so far.

Figure 11 shows the typical schematic flow of AQCS at coal-fired plants along with the concept of mercury removal. Elemental mercury is difficult to remove across whole AQCS, however oxidized form such as HgCl_2 could be captured at Dry ESP or wet FGD.

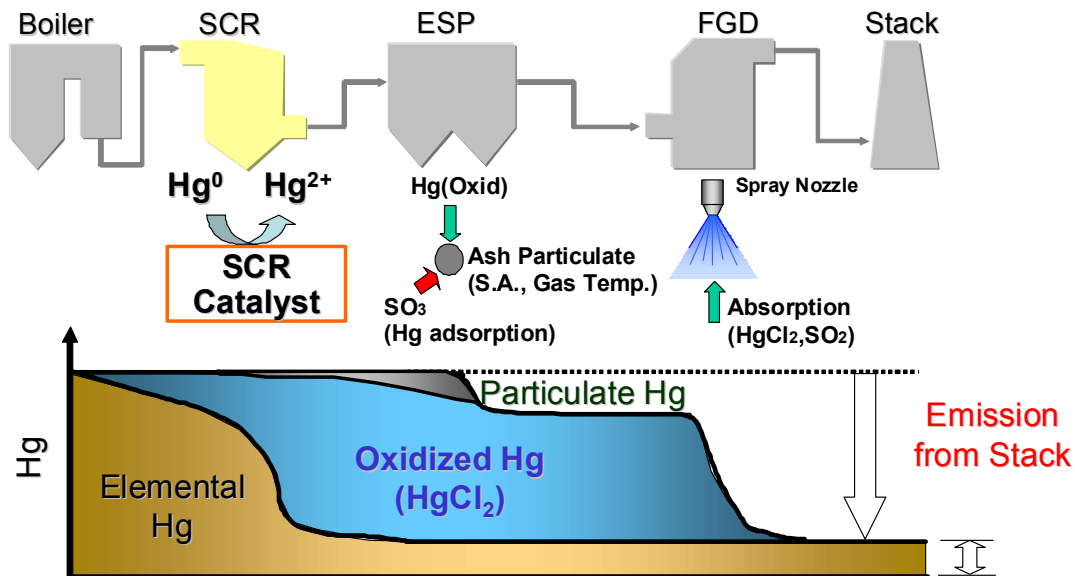





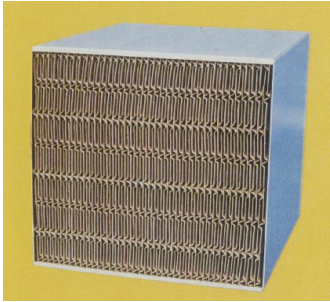
Figure 11 Outline of AQCS system

Hitachi's advanced mercury oxidation TRAC[®] catalyst has significantly high mercury oxidation activity while maintaining low SO_2/SO_3 conversion [6] and extensive durability and after field demonstrations in the U.S, TRAC[®] has been commercially utilized since 2007 with full mercury oxidation guarantees.

5.1 SCR-TRAC[®]

5.1.1 HITACHI'S Approach to Develop New SCR Catalyst

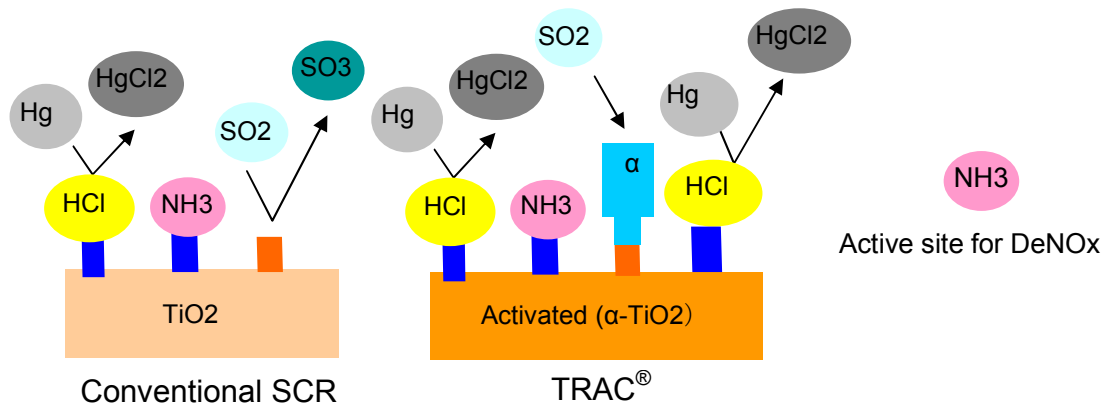
As shown in Figure 12, Hitachi conducted several verification and demonstration tests after several hundreds of screening tests at laboratory test facility for mercury oxidation catalyst to demonstrate the technology and confirm their reliability in the actual plant conditions. Standardization of fabrication methods is the final step in commercialization. This step by step development for technology reliability is the basis of Hitachi policy.

1. Laboratory Test Screening/Deterioration study of catalyst samples • Simulated gas w/o SO ₃	2. Verification Test Performance Test Coal fired flue gas • W/ SO ₃	3. Demonstration Test • Pilot (SSR) tests • Durability at actual plant • w/SO ₃	4. Practical Application • Standardization of design and manufacturing method.
			

Figures 12 Hitachi’s Approach for Development of New SCR Catalyst

5.1.2 TRAC[®]

Figure 13 shows the proposed reaction model on mercury oxidation catalyst compared with conventional SCR catalyst. Hitachi Mercury Oxidation catalyst, named TRAC[®] developed to enhance mercury oxidation activity while keeping SO₂ conversion rate as shown in Figure 14 by means of addition of new chemical to activated TiO₂ base oxide and manufacturing process.



5.1.3 The Effect of Temperature and Halogen on Mercury Oxidation Activity

A large-scale slipstream test was conducted to see the effect of temperature and halogen at Mercury Research Center (MRC) with low sulfur bituminous coal. The SSR testing was conducted in 2009. At this test facility, Hitachi was also able to confirm the performance differences between our conventional SCR catalyst and TRAC[®] under certain flue gas conditions.

Figure 15 shows mercury oxidation activity for both conventional SCR catalyst and TRAC[®] against halogen (Cl) concentration and flue gas temperature respectively. As can be seen in the left side graph in Figure 10, TRAC[®] has excellent mercury oxidation activity in the test conditions even though mercury oxidation activity for conventional catalyst was decreased with halogen concentration tested. And also the performance of TRAC[®] was stable even if flue gas temperature is high [7].

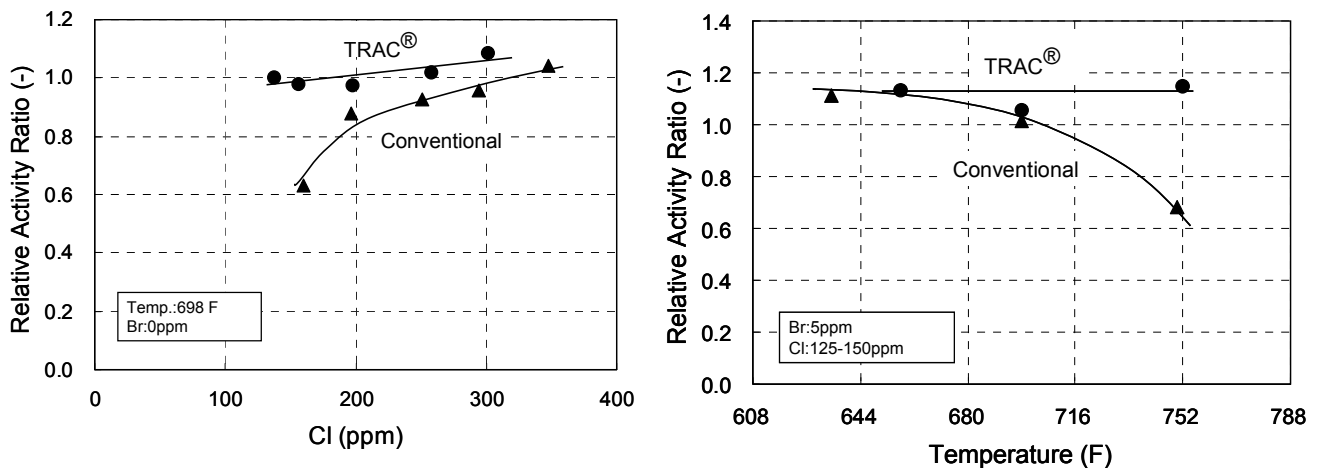


Figure 15 Mercury Oxidation Activity vs. Halogen(HCl) and Temperature

5.2 Hitachi's Latest Air Quality Control System (AQCS)

5.2.1 Mercury and SO₃ behavior across AQCS

The latest Hitachi AQCS eliminates HAP from flue gas by combination of TRAC[®], heat exchanger for flue gas cooling, dust collectors and wet FGD system [8,9]. The heat exchanger is a proven finned tube structure and decreasing flue gas temperature at the inlet of dry ESP will be great help to remove Hg and SO₃.

Figure 16 illustrates the configuration of the 1.5MWth pilot test facility and the sampling locations of flue gas and accumulated ash. Furnace exhaust gas was cooled by heat exchanger and introduced into the AQCS test facility, which consisted of SCR, gas cooler, dry ESP and wet FGD. We have conducted a large number of tests to evaluate behavior of mercury and SO₃ under various operating conditions for years.

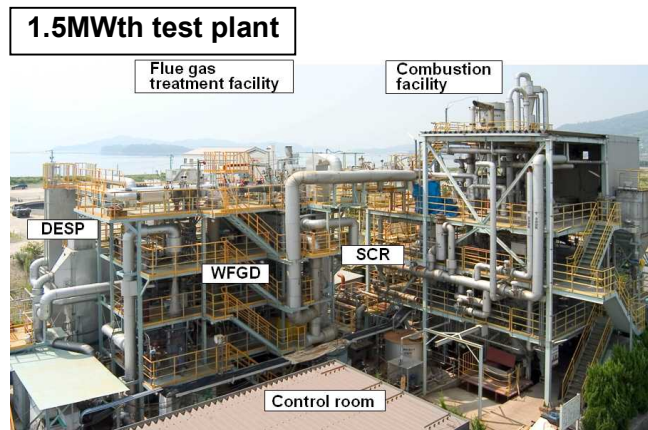
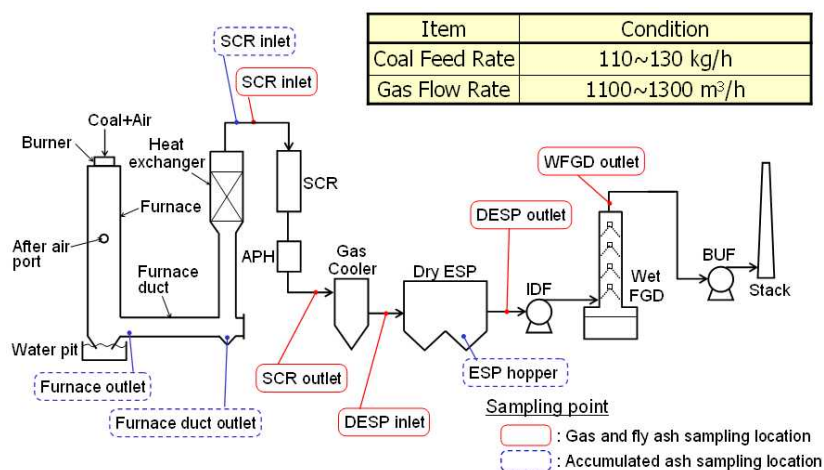


Figure 16 Schematic Flow of Pilot Test Plant and Sampling Locations

The flue gas temperature at dry ESP inlet was controlled at 160 °C (320 ° F) and 90 °C (194 ° F) by the gas cooler and the effect of dry ESP temperature on the behavior of SO₃, mercury was investigated. These components in flue gas were measured at SCR inlet, dry ESP inlet, dry ESP outlet and wet FGD outlet. In this test program, coal-A and coal-B from North America were used. Sulfur content of coal-A was low on the other hand coal-B was defined as a high sulfur bituminous coal.

5.2.2 Behavior of SO₃

The effect of the “gas cooler system” in new AQCS system on SO₃ removal was studied with high SO₃ using coal-B. Figure 17 shows changes in gaseous SO₃ ratio from SCR outlet to dry ESP outlet.

Gaseous SO₃ at the inlet of dry ESP was remarkably reduced along with drop in temperature of flue gas from 160°C (320 ° F) to 90°C (194 ° F). As the dry ESP inlet temperature fell below SO₃ acid dew point, gaseous SO₃ was condensed on ash and removed from the flue gas. The total SO₃ in flue gas at dry ESP outlet was less than 1ppm, even if high sulfur coal was used as shown Figure 18.

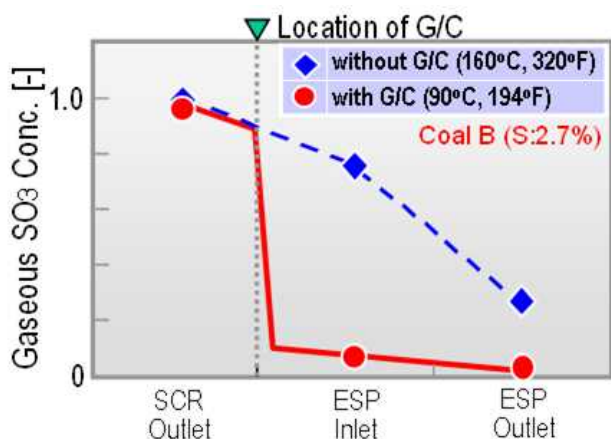


Figure 17 Gaseous SO₃ in Flue Gas

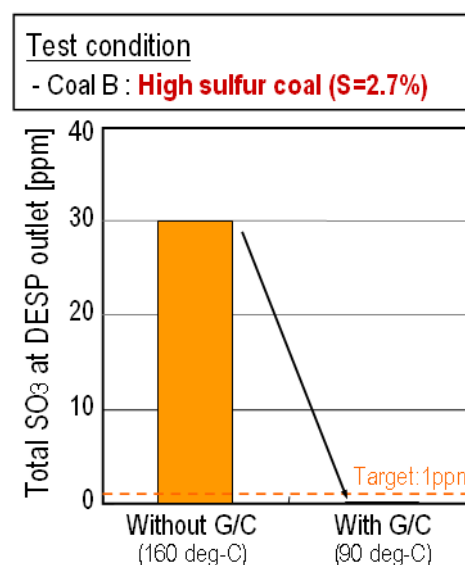


Figure 18 SO₃ Removal on the Gas Cooler System

5.2.3 Behavior of Mercury

Figure 19 shows the mercury removal efficiency across dry ESP with controlling gas temperature at the inlet of dry ESP. The mercury removal efficiency increased as the gas temperature decreased. The mercury removal efficiency of the lower sulfur coal was greater than that of the higher sulfur coal, because SO_3 occupied the adsorption sites on the surface of ash particles and mercury adsorption was prevented.

Figure 20 shows the changes of mercury concentration in the flue gas from SCR inlet to wet FGD outlet with or without alkali sorbent injection. Alkali sorbent was injected into the flue gas at SCR outlet. Elemental mercury (Hg^0) was converted into oxidized form (Hg^{++}) across SCR and almost all of the mercury was oxidized form at dry ESP inlet. The mercury removal across dry ESP with alkali sorbent injection was greater than without alkali sorbent injection, because of preventing occupancy of the adsorption sites on the surface of ash particles from SO_3 .

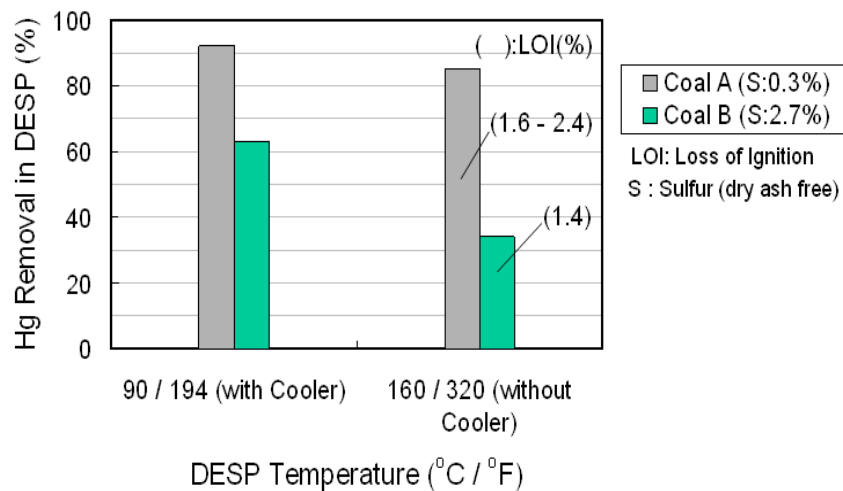


Figure 19 Relationship between Dry ESP Temperature and Hg Removal across Dry ESP

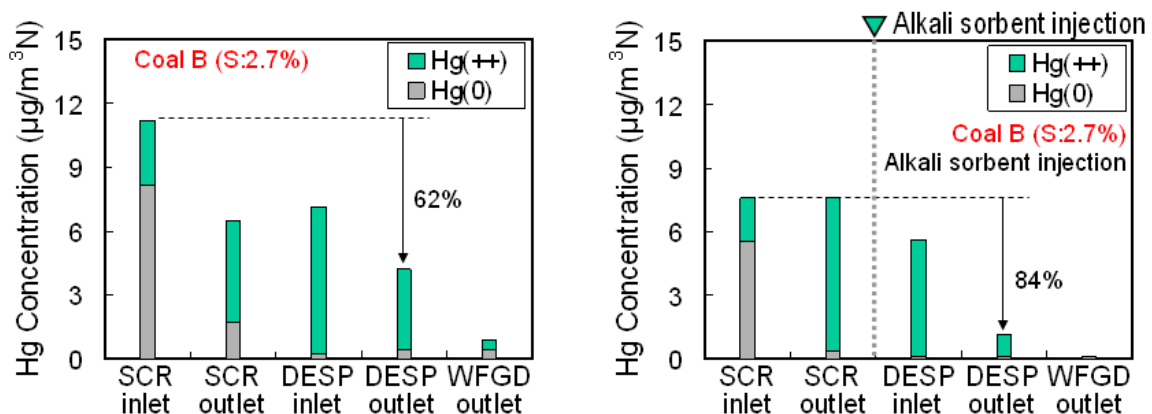


Figure 20 Effect of Alkali Sorbent Injection on Hg removal

6. CO₂ Reduction technologies

Increasing energy efficiency, utilizing low carbon fuels, and carbon sequestration are keys to reduction of greenhouse gas emissions. Technologies of CO₂ reduction from power plants are important as a substantial portion of greenhouse gas emissions are from power generation sources, especially coal-fired power plants. Hitachi has been developing four specific CO₂ reduction technologies of (1) 700C-class A-USC (described in the previous section), (2) IGCC, (3) Oxy-fuel combustion and (4) CO₂ scrubbing. In this section, Oxy-fuel combustion and CO₂ scrubbing are described hereinafter.

6.1 Oxy-fuel combustion

Oxy-fuel combustion is an effective method in removing all CO₂ from combustion flue gas. Oxy-fuel combustion systems can be retrofitted to existing power plants with no change to plant water-steam cycles with only limited modifications to the boiler. Hitachi's oxy-fuel combustion system has the following features;

- 1) Mercury and SO₃ removal by decreasing flue gas temperature at DESP inlets with a gas cooler system.
- 2) A large increase in power of LP turbine output (18MW for a 500MW class unit) as the gas cooler preheats boiler feed water and reduces steam extraction from LP turbine.
- 3) Improvement of plant net efficiency by the gas cooler system (2.0 percents).
- 4) Stable combustion under low O₂ concentration of primary gas with a new burner.
- 5) Oxy-fuel combustion with O₂ concentration at 27~30 % takes the same heat absorption as air combustion.

Flue gas treatment system with a gas cooler before the DESP previously explained is also applied to oxy-fuel combustion system. In oxy-fuel combustion, N₂ is replaced with CO₂, which has more inactive property than N₂, and flame stability is worse in CO₂ + oxygen condition than in N₂ + oxygen condition under the same O₂ concentration. Under an oxy-fuel condition of low O₂ concentration in primary gas supplied into pulverizer, flame stability is an issue to be solved. BHK applied the NR-LE Burner specially developed for lignite fired boilers where low oxygen gas is used as the primary gas. The NR-LE Burner has the same basic features of the HT-NR3 Burner as described in the previous section and air nozzles have been installed additionally in the fuel nozzle to increase oxygen concentration near the flame stabilizing ring to enhance flame stability. By this consideration, smooth change over operations between air combustion mode and oxy-fuel combustion mode and very stable flame under low oxygen primary gas condition of oxy-fuel combustion mode are achieved.

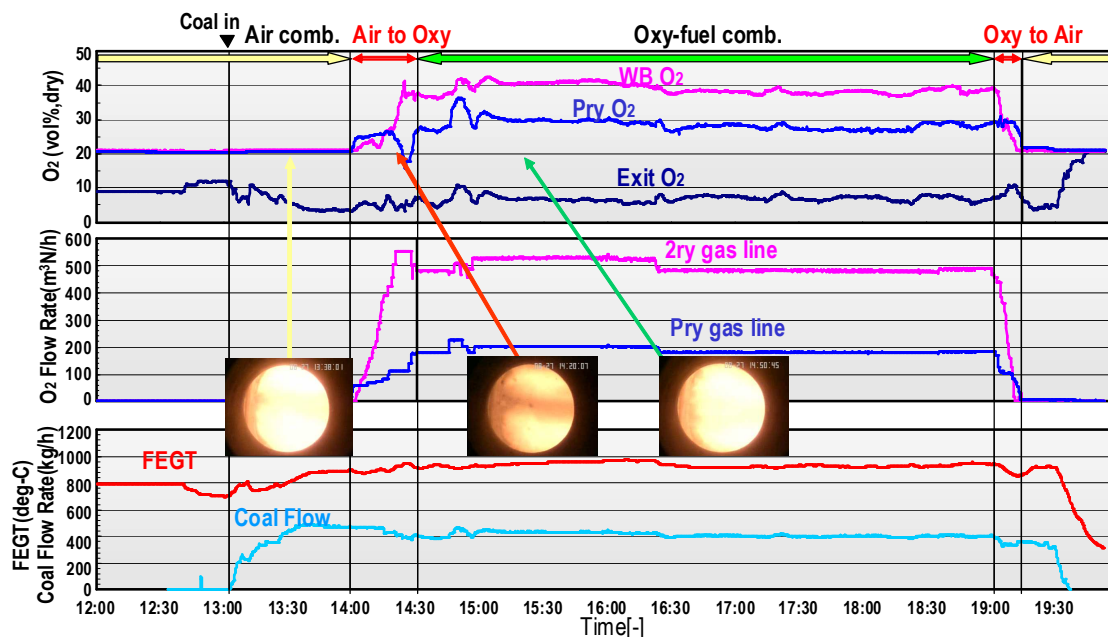


Figure 21 Time Trend Chart and Pictures of Burner Flames during Oxy-fuel Combustion Test

6.2 CCS

Hitachi also has been developing a new amine-based scrubbing technology for capturing carbon dioxide (CO₂) in the flue gas for coal-fired power plants. The technology features an advanced AQCS for flue gas pre-cleaning, a low energy-consuming, highly oxygen-resistant amine-based scrubbing system, and a highly efficient steam extraction system. H3-1 is the latest solvent Hitachi has developed so far has been demonstrated at pilot scale and slipstream test facilities at EERC (Energy and Environmental Research Center) and NCCC (National Carbon Capture Center) in the U.S. from 2010 to 2012. As shown in Figure 22, the main system components are a pre-scrubber, an absorber, a stripper and a reboiler and the energy recovered by the gas cooler can be utilized for the CO₂ capture system to reduce its overall energy consumption.

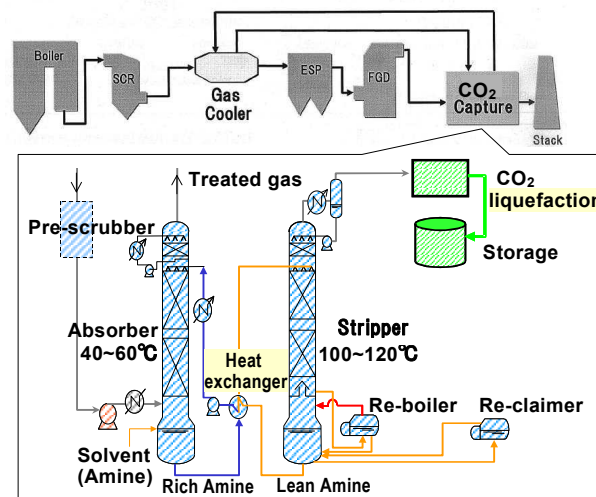


Figure 22 Post-Combustion CO₂ Capture Process

6.2.1 Testing Facility in Akitsu Works

Figure 23 shows a schematic flow of the test facility in the CO₂ capture R&D center at Akitsu works of BHK in Japan. Simulated flue gas containing air and CO₂ is saturated with H₂O by mixing with steam, and fed into the bottom of the absorber. CO₂ is scrubbed in the absorber by H3-1 solvent and the solvent is circulated to feed the stripper. CO₂-rich H3-1 solvent is heated by steam which is generated in the reboiler, and CO₂ is stripped.

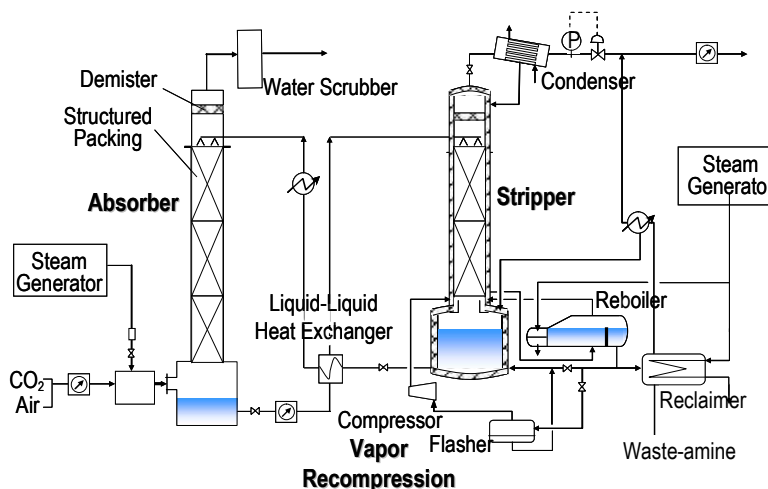


Figure 23 Test Facility in Akitsu works

Figure 24 shows the relationship between the liquid-gas ratio (L/G) and CO₂ removal efficiency at two different inlet levels of CO₂. And based on those results, the volumetric mass transfer coefficient (K_{ga}) is evaluated as shown in . Figure 25. K_{ga} increases with increasing L/G. These data are used to design absorber and stripper columns.

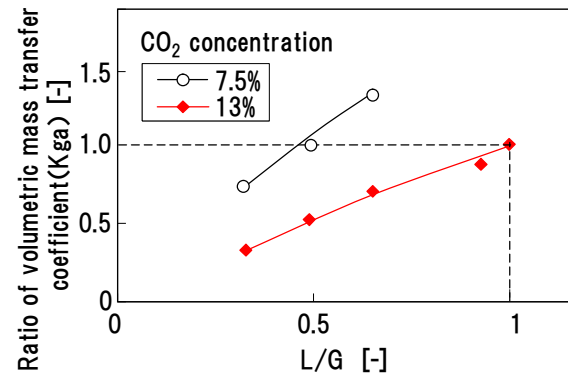
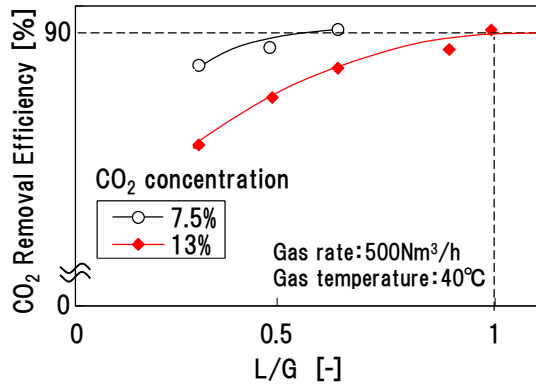


Figure 24 Relationship between L/G and CO₂ Removal Efficiency

Figure 25 Relationship between L/G and K_{ga}

6.2.2 EERC Test Results

According to Honoki et al[10], the performance of H3-1 solvent was evaluated with the pilot scale test facility at EERC in the US. Figure 26 shows the EERC pilot plant equipped with a coal fired furnace, flue gas clean up system and CO₂ capture facility. Coal firing flue gas passes through the SCR, dry ESP and wet FGD where NO_x, particulate matter and SO_x were removed and the flue gas temperature was decreased. This cooled flue gas down to 30-50°C was introduced to the CO₂ absorber. The pilot plant was operated using H3-1 under various conditions and the performance results were compared with MEA.



Figure 26 EERC Pilot Plant

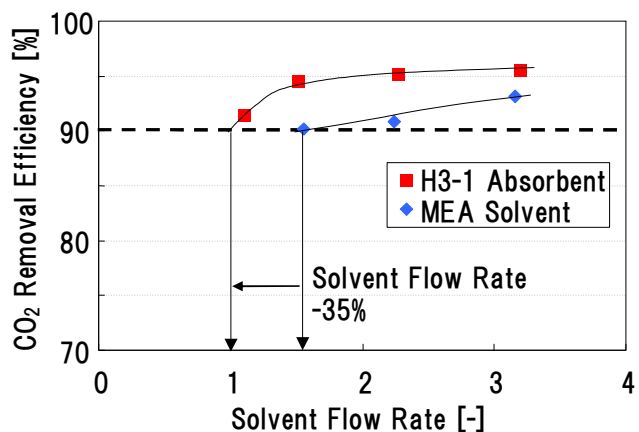


Figure 27 L/G vs. CO₂ Removal Efficiency

Figure 27 shows the relationship between the solvent flow rate and CO₂ removal efficiency. At 90% CO₂ removal efficiency, the required solvent recirculation rate for H3-1 was about 35% lower than that for MEA. The heat duty in the reboiler when using H3-1 as the solvent was about 30% lower than with MEA.

6.2.3 Test at NCCC

Hitachi H3-1 solvent was tested in the pilot scale test facility at NCCC [11]. The flue gas from a coal-fired boiler was fed to the slipstream test facility after passing through the SCR and wet-FGD. This flue gas was then introduced to the pre-scrubber where SO₂ and other trace components were removed. The flue gas was then passed through a cooler-condenser where the gas temperature was reduced to the controlled level, before being introduced to the CO₂ capture system. Figure 28 shows flow diagram and the photo of the pilot plant facility. This CO₂ capture pilot facility is equipped with an absorber, stripper, heat exchangers, washing tower, inter coolers and reboiler. Over 1,300 hours of testing of the H3-1 solvent was completed.

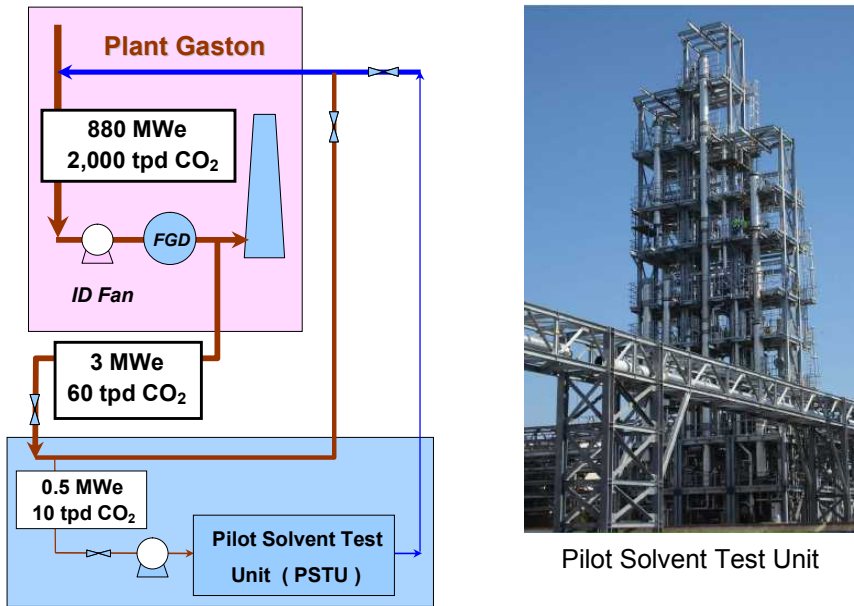


Figure 28 Schematic System Flow of the Pilot-Scale Facility

Figure 29 shows the results of the regeneration energy using H3-1 compared with that when 30 wt% MEA was tested at the NCCC test facility. Both tests were performed under the same inlet flue gas flow rate of approximately 1,800Nm³/h, and with three packed beds in the absorber. The regeneration energy required by H3-1 is about 67% of that required by 30 wt% MEA, and the CO₂ removal efficiency using H3-1 is higher than that for 30 wt% MEA.

Table 1 NCCC Test Conditions

Inlet Gas Flow Rate	1400-2100 Nm³/h
Solvent Flow Rate	3,000-7,800 L/h
CO₂ Concentration	11-13 %
NO_x Concentration	50 ppm
SO₂ Concentration	0.5 ppm

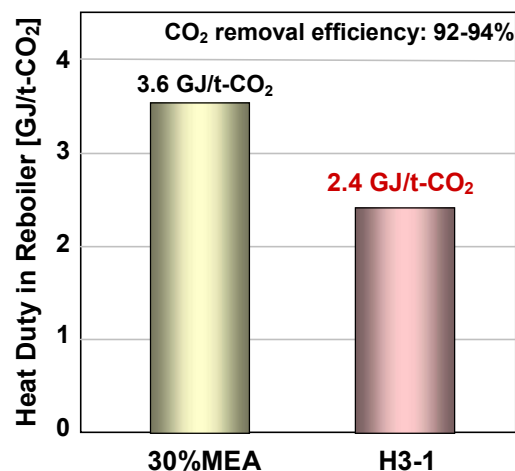


Figure 29 Performance Evaluation at NCCC: Heat Duty

7. Conclusion

Hitachi has been developing the new technologies, not only for combustion technology but for environmental control systems including SCR, ESP and wet FGD, as a whole plant supplier for thermal power plants. In addition, Hitachi also developed a proprietary amine-based solvent, H3-1 for CO₂ removal for coal firing flue gas toward zero emission policy.

The results are the following.

1. Babcock-Hitachi has excellent USC power boiler technologies and is establishing manufacturing process of A-USC boilers.
2. High efficient low NO_x burners and systems have been applied and contributed to worldwide environmental protection to reduce NO_x emission without increasing trade-off unburned material.
3. Unique oxy-fuel combustion system can be applied to existing boilers with stable, reliable and high efficient operation without remarkable modification.
4. Mercury Oxidation SCR catalyst, TRAC[®] has been supplied to the actual coal firing plant and operated from 2007 without any troubles.
5. Gas cooler system with TRAC[®] could improve SO₃, mercury removal across Dry ESP.
6. Effect of high sulfur condition on mercury removal was mitigated by alkali sorbent injection.
7. Amine loss of the advanced H3-1 solvent is about 86% lower than that for 30% MEA solution.
8. Solvent recirculation rate required for 90% CO₂ capture using H3-1 is about 35% lower than that with MEA. The heat duty in reboiler when using H3-1 is about 30% lower than that with MEA.

References

1. M.Fukuda, E.Saito, Y.Tanaka, T.Takahashi, S.Nakamura, J.Iwasaki, S.Takano and S.Izumi, "Advanced USC Technology Development in Japan", presented at 6th International Conference on Advances in Materials Technology for Fossil Power Plants, Santa Fe, New Mexico (September 2010)
2. G.Bao, T.Sato, Y.Fukuda, and K.Mitsuhata, "Narrow Gap HST Welding Process and Its Application to Candidate Pipe Material for 700°C USC Boiler Component", presented at 34th MPA-SEMINAR and VGB-Symposium on Materials and Components Behaviour in Energy & Plant Technology, Stuttgart, Germany (October 2008)
3. T.Sato, Y.Fukuda, K.Mitsuhata and K.Sakai: "The Practical Application and Long-term Experience of New Heat Resistant Steels to Large Scale USC Boilers", presented at 4th International Conference on Advances in Materials Technology for Fossil Power Plants, Hilton Head Island, South Carolina (October 2004)
4. F. Koda et al; Development of Pulverized coal Low NO_x Burner using In-Flame NO_x Reduction, Environmental research, Vol.87 (1992.9)
5. Anthony Favale, Stephen Guglielmo, and Peter Jin, Hitachi Power Systems America Ltd.; Yoshinori Nagai, Babcock Hitachi, K.K., Japan; and Corey Tyree, Southern Company Research & Environmental Group, An SCR Can Provide Mercury Removal Co-Benefits, Power No.155, Vol.10, October, 2011
6. Keiichiro Kai, Hirofumi Kikkawa, Yasuyoshi Kato, Yoshinori Nagai, William J Greta, SCR Catalyst with High Mercury Oxidation and Low SO₂ to SO₃ Conversion, Power Plant Air Pollutant Control Megasympoium, Baltimore, MD, August 28-31, 2006
7. Yoshinori Nagai, Yasuyoshi Kato, Keiichiro Kai, Hirofumi Kikkawa, Isato Morita, Katsuhiro Yashiro, Commercialization of Mercury Oxidation Catalyst (TRAC[®]) for Coal-Fired Power Plants, The 11th China-Japan Symposium on Coal and C1 Chemistry, August 3-7, 2011
8. Kikkawa, H., Nakamoto, T., Study on Measuring Method of Mercury in Flue Gas and 1st Application for Coal Fired Test Plant, 27th International Technical Conference on Coal Utilization & Fuel System, March, 2002.
9. Muramoto, T., New Fuel Gas Treatment System for 1,050MWe Coal Fired Plant, Power-Gen International 2003
10. Honoki, et al, GHGT2013, Hitachi's Carbon Dioxide Scrubbing Technology with H3-1 Absorbent for Coal Fired Power Plants, Kyoto, 19-22, November, 2012
11. Miyamoto, et al EUEC 2013, Hitachi's Carbon Dioxide Scrubbing Technology with H3-1 Absorbent for Coal Fired Power Plants, Phoenix, AZ, USA, 30, January, 2013