

# **LATEST EXPERIENCE OF COAL FIRED SUPERCRITICAL SLIDING PRESSURE OPERATION BOILER AND APPLICATION FOR OVERSEAS UTILITY**

**Hajime Kimura  
Junichiro Matsuda  
Kazuhito Sakai  
Babcock-Hitachi K.K.**

## **ABSTRACT**

In the fossil power utility field, a supercritical sliding pressure operation type unit has been developed as the most advanced generating system combining higher efficiency, with low emissions technology. Globally, this type of system has been the major trend for recent thermal plants. The use of low grade coals i.e. low volatile, high ash content, for economic reasons provides additional challenges to meet the international demands for improved efficiency and low emissions.

Babcock-Hitachi K.K. (BHK) has supplied a number of coal-fired boilers for thermal power plants in Japan. The contribution to the improvement of power plant efficiency and the success of reduction in NO<sub>x</sub> emission has been favourably received by all utilities.

Our most recent boiler experience relates to 1050MW power plant (Electric Power Development Co. Japan, Tachibana-Wan Thermal Power Station No.2 boiler; 3000t/h steam output at Maximum continuous rating) combining advanced steam conditions; pressure 25.0MPa, temperature 600°C/610°C and achieved the guaranteed boiler efficiency and strict requirements for NO<sub>x</sub> emissions and unburned carbon in ash throughout the performance test. Subsequently, a 1000MW

power plant (The Tokyo Electric Power Co. Inc. Japan, Hitachi-Naka Thermal Power Station No.1 boiler, 2870t/h steam output at Maximum continuous rating) is now under commissioning, to provide similar advanced steam conditions, pressure 25.4MPa and temperature 604°C/602°C. The boiler was designed to meet challenging technical improvements and will be a benchmark for the boilers with High Capacity Coal Fired Supercritical Sliding Pressure.

BHK have established a standardised design concept for coal fired supercritical sliding pressure operation boilers for worldwide utilities based on our experience of designing and constructing similar units over the previous decade.

This paper describes the principal characteristics of a coal fired supercritical sliding pressure operation boiler and suitable design parameters to utilise various grades of coal, considering economics and reliable operation in accordance with our experiences in Japan and in the export market for this technology.

## **1. Introduction**

In the late 1950s, in Japan, the number of large capacity supercritical pressure oil fossil fired power plants increased as an alternative to former smaller capacities sub critical pressure fossil fired plants using domestic coal for fuel. In the early 1970s, energy dependence on imported oil reached approximately 80%. Significant oil price increases and subsequently occurred twice, in 1973 and 1978, initiating a total review of domestic electricity economics triggered a need for fuel diversification and energy saving. At that time, the demand for LNG increased as the most immediate effective substitute fuel. After the 1980s, imported coal became the main energy resource to coping with a stable supply and the mixing of electric power resources. With the increase of nuclear power plants to accommodate base load operations, the associated variations of electric load demands mean that the most new power units tended to be designed for cyclic duties.

Fig. 1 shows the general trends of utility boiler supplied by BHK in Japan. Various capacities of BHK Benson Boilers have been supplied to cope with aforementioned utility power plants demands. Subsequently, improvement in performance and technology has been the subject of BHK resource,

which will be incorporated into future project as they become available.

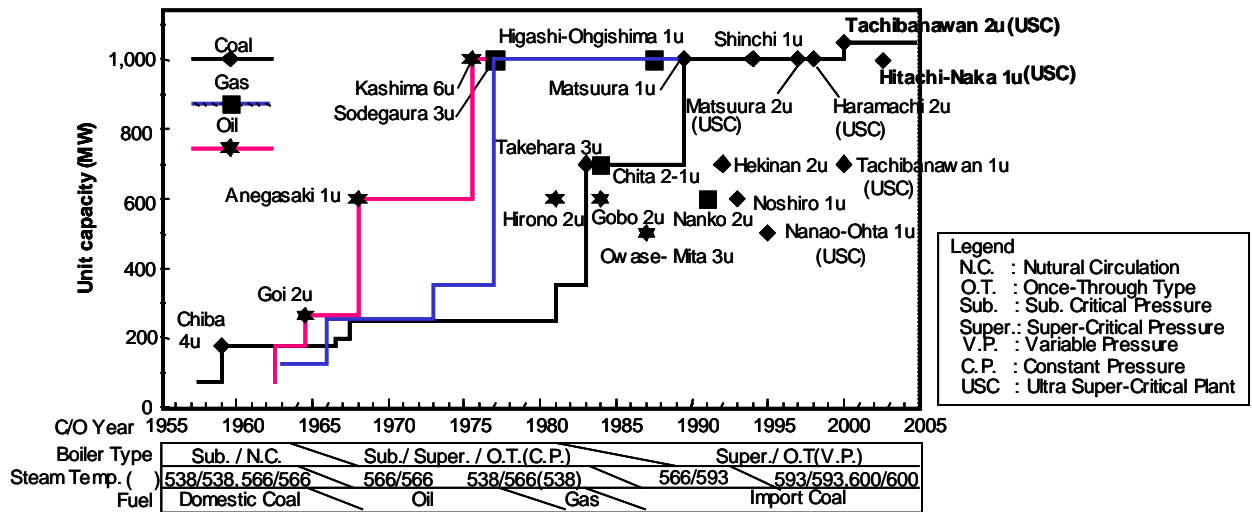


Fig. 1 General Trends of Utility Boilers Supplied by BHK in Japan

## 2. Improvement of Steam Conditions

Higher steam conditions were initiated through global environmental issues, i.e. to reduce greenhouse gases, especially CO<sub>2</sub> emissions and by improving plant efficiency. Fig. 2 shows a record of steam parameter improvements established by BHK in Japan. The first ‘USC (Ultra Super Critical)’ plant in Japan was built in 1989 employing gas fired boilers with steam conditions of 31MPa/566°C/566°C/566°C. At that time, the newly installed coal fired plants had a typical live steam pressure of 24.1MPa, though steam temperatures increased gradually. The most advanced steam condition currently in commercial operation in Japan is 25.0MPa/600°C/610°C, at the Tachibana-Wan No. 2 boiler of Electric Power Development Co. Ltd. supplied by BHK in 2000.

This trend is being maintained with plants currently under commissioning, and with Hitachi-Naka No. 2 Unit of The Tokyo Electric Power Co. Inc., the steam parameters of which are 25.4MPa/604°C/602°C.

Fig. 2 and 3 show typical improvements of steam condition and plant efficiency for the latest plant.

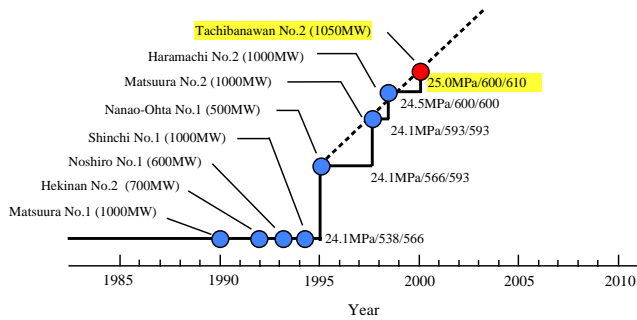


Fig. 2 Improvement of Steam Condition in Japan

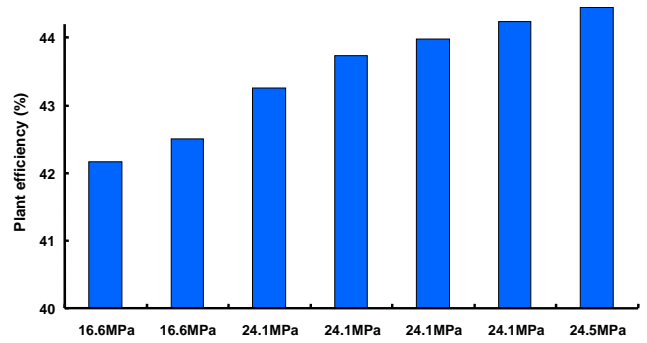


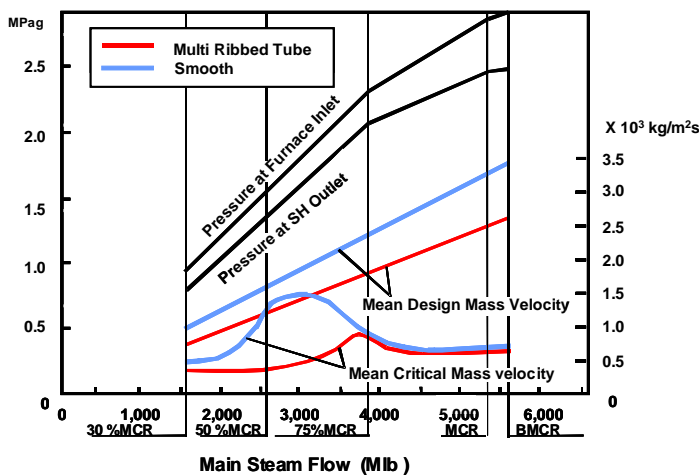
Fig. 3 Improvement of Plant Efficiency

### 3. Boiler Design Feature

#### 3.1 Once-through Boiler (BENSON boiler for sliding pressure operation)

Benson type boilers have been developed and designed for variable sliding pressure operation plants of high efficiency at all loads, which is suitable for both base and middle load operations. The start-up system consists of a steam/water separator, a boiler circulation pump and associated piping, which ensure a quick, smooth start-up and shutdown of the plant and easy operability. Table 1 summarises the design feature of the BENSON boiler in comparison with other boiler types.

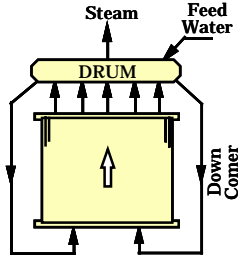
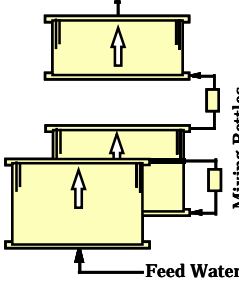
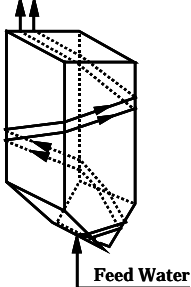
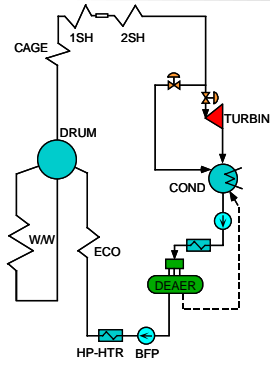
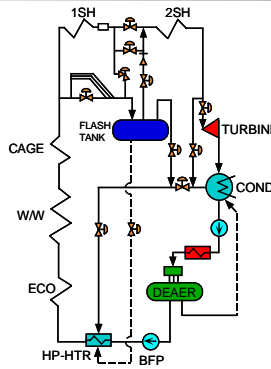
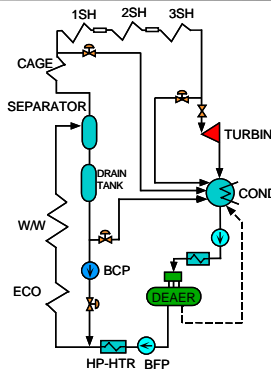
A spirally wound water wall construction with ribbed tubing is applied to the furnace to enable have sufficient mass flow velocity in the water wall tubes under variable loads to prevent departure from nucleate boiling (DNB) and to achieve uniform water temperature distribution at the furnace outlet when operating below critical pressure and without pseudo DNB when operating above critical pressure (Fig. 4). All heated water walls are arranged with upward fluid flows.



Ribbed Tube

Fig.4 Comparison of Mass Velocity in Furnace Wall Tube in Sliding Operation Mode

Table 1 Boiler Type and Furnace Construction

	NC Boiler	UP Boiler	Benson Boiler
Furnace Construction	 <p>Vertical Type</p>	 <p>Vertical Type (UP-UP Type)</p>	 <p>Spiral Type</p>
Operating Pressure	Sub-Critical (Constant or Sliding)	Sub-Critical or Supercritical (Constant Pressure)	Sub-Critical to Supercritical Region (Sliding Pressure)
Mixing Bottles	Mixing Bottles are not Necessary	Mixing Bottles are Necessary to Reduce Effect of Heat Flux Unbalance	Mixing Bottles are not Necessary By Spiral Type Water Wall
Applicable Steam Pressure	Subcritical	Supercritical & Subcritical	Supercritical & Subcritical
Through Furnace Enclosure Tubes			
Fluid Stability	Self Balance	Base	Much Better
Temperature Uniformity	Better	Base	Much Better
Mass Flow Rate	Approx. 13%	100%	100%
Variable Pressure ?	YES	NO	Wide Range
Allowable Min. Load (%)	15	35 - 45	25 - 35 (OT Mode) 15 (Circ. Mode)
Load Change Rate	Base	Slightly Higher	Higher
Start-up Time (min.) (Hot start)	120 - 150 with TB By-pass	250	120 - 150 with TB By-pass
Furnace Enclosure Construction	Vertical	Vertical	Spiral
Tube O/D (mm)	57.0 - 63.5	22.5 - 31.8	31.8 - 38.1
Max. Unit Capacity in Operation	800MW	1,300MW	1,050MW
Furnace Construction			
Start-up Bypass System	<ul style="list-style-type: none"> <li>•Not installed</li> <li>•Operation of drain valves and vent valves is necessary</li> </ul>	<ul style="list-style-type: none"> <li>•Main valve is installed in the main steam line</li> <li>•Shift operation of start-up valves is necessary</li> <li>•Operation of drain valves and vent valves is necessary</li> </ul>	<ul style="list-style-type: none"> <li>•Simplified start-up bypass system</li> <li>•Shift operation of start-up valves is not necessary</li> <li>•Operation of drain valves and vent valves is necessary</li> </ul>
Heat Loss during Start Up	<ul style="list-style-type: none"> <li>•Continuous blowing (in case of bad water quality)</li> </ul>	<ul style="list-style-type: none"> <li>•Warming of start-up bypass system</li> </ul>	<ul style="list-style-type: none"> <li>•Warming of start-up bypass system</li> <li>•Heat recovery of circulated water by BCP</li> </ul>

Notes NC:Natural Circulation OT:Once-Through Circ.:Circulation O/D:Outside Diameter

### 3.2 Sliding Pressure Operation

The sliding pressure operation is a control system in which the main steam is controlled by sliding pressure in proportion to the generation output. Steam quality at the turbine inlet can be changed at constant volume flows while keeping the turbine governing valve open. Utilising sliding pressure, the thermal efficiency of the steam turbine is improved at partial operating loads through decreasing thermodynamic efficiency as follows, by comparison with constant pressure type operation:

- (1) A smaller governing valve loss enables improvement of high pressure turbine internal efficiency
- (2) Decrease of feed water pump throughput
- (3) Boiler reheat steam temperature can be maintained at higher levels because of higher temperatures in high-pressure turbine exhaust steam.

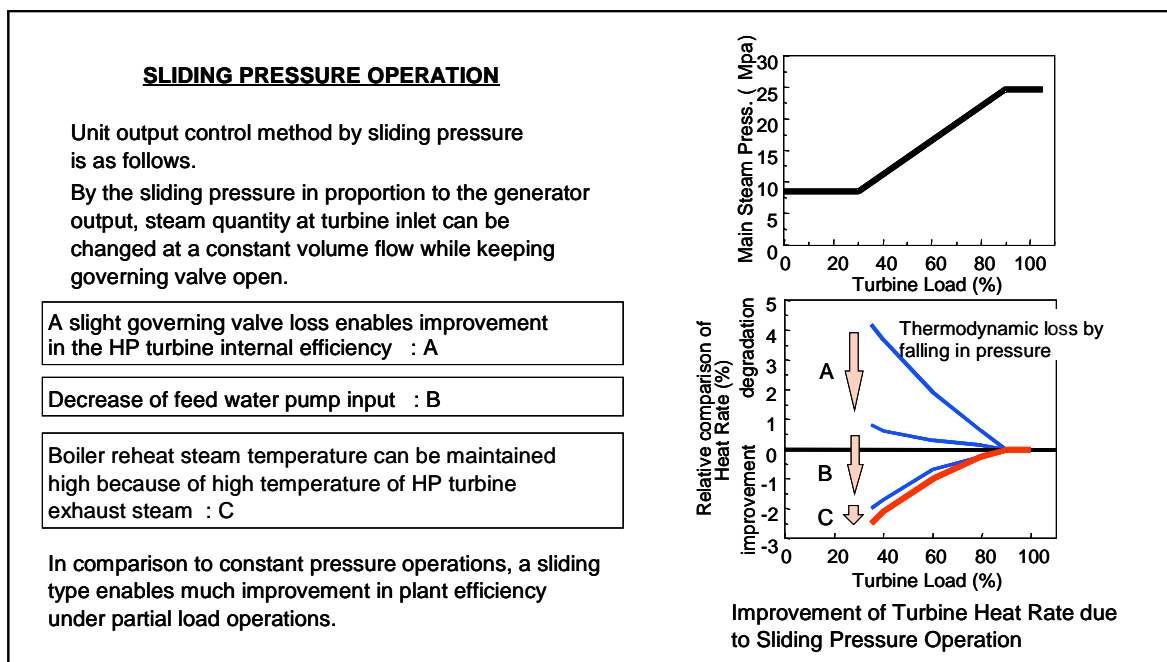


Fig. 5 Feature of Coal Firing Supercritical Sliding Pressure Operation Boil

## **4. Pressure Parts Material**

### 4.1 Materials for conventional super critical boilers

Table 2 lists the typical materials used for conventional super critical boilers with steam conditions of 24.1MPa/538°C/566°C, and Fig. 6 shows allowable stresses of the boiler materials. The selection of appropriate and economical material for boiler pressure parts depends on a number of factors such as

strength properties, corrosion resistance, metallurgical stability and so on. It is therefore necessary to select the optimum steel, considering all relevant factors at anticipated metal temperatures.

Table 2 Typical Materials for Conventional Super Critical Boiler

Pressure part		Steam conditions:24.1MPa/538C/566C	
		Metal Temperature	Materials
Tubing	Economizer	300 ~ 350C	Carbon steel(STB510)
	Furnace wall	350 ~ 500C	0.5Mo(STBA13) 0.5Cr0.5Mo(STBA20) 1Cr0.5Mo(STBA22)
	Superheater	450 ~ 590C	0.5Mo(STBA13) 0.5Cr0.5Mo(STBA20) 1Cr0.5Mo(STBA22) 2.25Cr1Mo(STBA24) 18Cr10NiTi(SUS321HTB)
	Reheater	350 ~ 610C	Carbon steel(STB340) 0.5Mo(STBA13) 1Cr0.5Mo(STBA22) 2.25Cr1Mo(STBA24) 18Cr10NiTi(SUS321HTB)
Header Piping	Superheater header	550C	2.25Cr1Mo(STPA24)
	Main steam pipe		
	Reheater header Hot reheat pipe	570C	2.25Cr1Mo (STPA24,SCMV4)

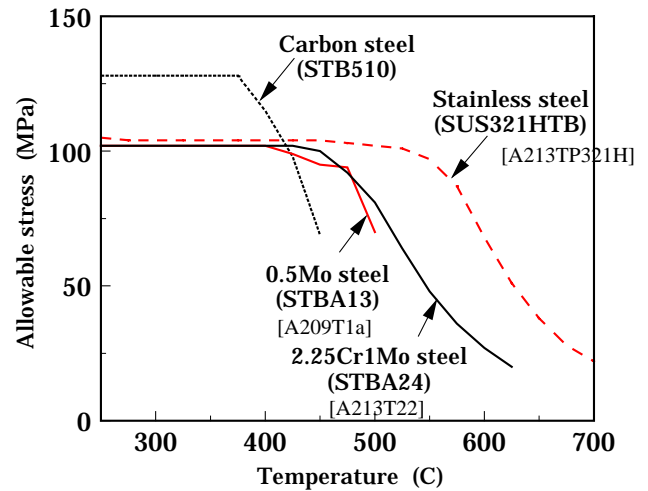


Fig. 6 Allowable Stresses of Boiler Materials

To establish adequate safety margins and service life, the characteristics of the steel must be given due consideration during the design phase. Economy dictates that the lowest alloy with properties suitable to the conditions should be used, stepping up from carbon steel to molybdenum steel and to chromium-molybdenum steel as temperatures increase. For metal temperatures approaching about 550°C, lower-alloy ferritic steels up to and including 2.25% chromium are usually considered adequate. Stainless steels are used at higher temperatures, where conditions require an increase in resistance to corrosion and oxidation. However, stainless steel tubes usually have a higher carbon content in order to increase creep rupture strength. In spite of the sensitisation due to the higher carbon content during the usage in elevated temperature service, no stress corrosion cracking has been experienced in stainless tubes. This may be related to the fact that the inside surface of tubes contacts with dry steam.

The steam headers and pipes connecting the boiler and turbine are highly important components of the power plant. Such piping must be carefully designed and erected to absorb thermal expansion and vibratory stresses. Some stainless steel piping previously used in the power plant industry exhibited

serious cracking problems caused by high thermal stresses due to higher thermal expansion coefficients, as experienced under service conditions<sup>1)</sup>. Therefore, such thick walled components should be constructed using ferritic type steel pipes whose thermal expansion coefficient is relatively low.

4.2 Materials for advanced super critical boiler

Fig. 7 shows a comparison of allowable stresses between conventional and advanced chromium molybdenum steel pipe material. For high temperature headers and pipes associated with superheaters and reheaters, STPA28 (Mod.9Cr1Mo) developed by Oak Ridge National Laboratories is suitable due to its high temperature strength and excellent resistance to oxidation. Since the late 1980's the steel [STPA29] has been widely used for advanced power plants with the steam conditions of approximately 25MPa/600°C/600°C in Japan and Europe. STPA29 (NF616) subsequently developed by Nippon Steel and SUS410J3TP (HCM12A) developed by Sumitomo Metal have higher creep strengths than that of STPA28 (T91), and these steels have been used for an advanced power plant with steam conditions of 25MPa/600°C/610°C.

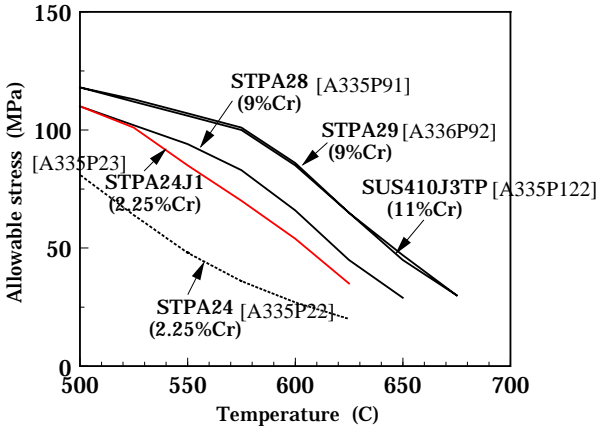


Fig. 7 Comparison of Allowable Stresses between Conventional and Advanced CrMo Steel Pipes

Fig. 8 shows a comparison of allowable stresses between conventional and advanced stainless steel tubes. Newly developed austenitic stainless steels such as SUS304J1HTB (SUPER304H) developed by Sumitomo Metal and SUS310J2TB (NF709) developed by Nippon Steel have extremely high creep rupture strength and the allowable stresses are twice as high value compared to SUS321HTB at

650°C. These steels have been applied to high temperature superheater tubes. For severe corrosion loads SUS310J3TB (HR3C) developed by Sumitomo Metal can be used because of its higher chromium content.

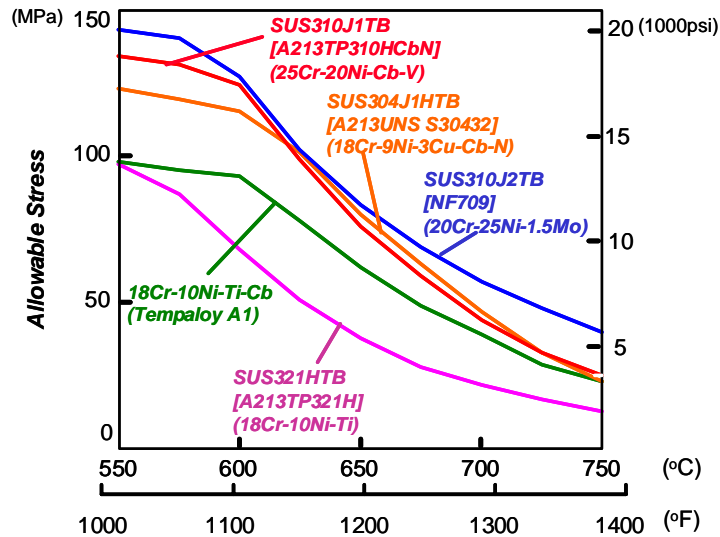


Fig. 8 Comparison of Allowable Stresses between Conventional and Advanced Stainless Steel Tubes

Another issue that must be considered when selecting material for high temperature tubing is the resistance to coal ash corrosion caused by coal sulphur content. Fig. 9 shows the effect of SO<sub>2</sub> content on corrosion loss. At SO<sub>2</sub> content of 0.1% or less (corresponding to about 1% sulphur in coal) or less, corrosion loss is negligible for austenitic stainless steels containing 18% chromium<sup>2)</sup>. When the sulphur content of coal is around 5% (corresponding to about 0.5% SO<sub>2</sub> in fuel gas), it will be necessary to use a high-chromium austenitic stainless steels such as SUS310J1TB (HR3C).

Fig. 10 shows the effect of steam temperatures on steam oxide scale thickness. With increasing steam temperatures, materials with an improved steam oxidation resistance require to be used for superheater and reheater tubes. Spalled steam oxide scales have the potential to plug steam flows and erode turbine components. The use of high chromium content or fine-grained stainless steel tubes is effective in minimizing steam oxidation troubles. Fig. 10 also shows that internally shotblasted stainless steel tube containing 18% chromium has similar resistance to steam oxidation as high chromium stainless steel at temperatures up to 700°C<sup>2)</sup>.

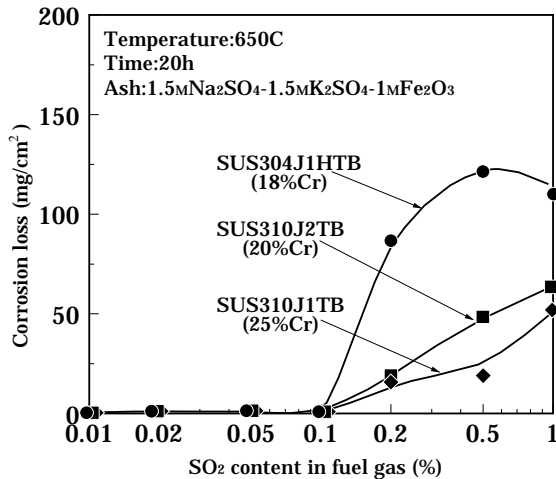


Fig. 9 Effect of SO2 Content on Coal Ash Corrosion Loss of Stainless Steel Tubes

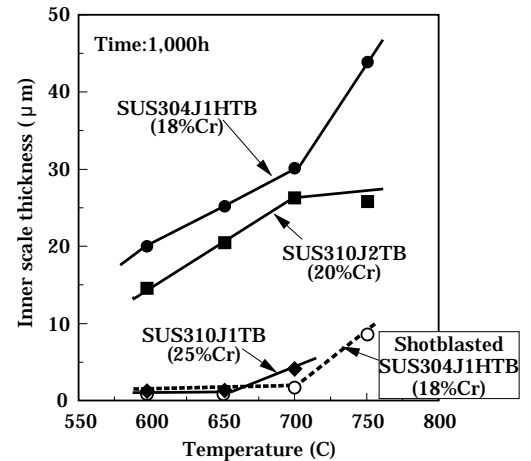


Fig. 10 Effect of Temperature on Steam Oxide Scale of Stainless Steel Tubes

### 5. Combustion System

For environmental protection, the Hitachi NR2 burner has been applied to achieve low levels of emission of NOx (oxides of nitrogen) and high levels of combustion efficiency. Following on from the development of Hitachi's NR burner in which an innovative concept of in-flame NOx reduction is applied, BHK further developed the NR2 and NR3 burners progressively. These burners features a stable and strengthened flame in terms of high-temperature reduction and achieved extremely low levels of NOx emission and high levels of combustion efficiency<sup>3)</sup>. The Hitachi NR burner series is based on an improved in flame NOx-reduction technology, which incorporates two innovative devices: a pulverised-coal (PC) concentrator and a space creator. The configuration of the burners is shown in Fig. 11.

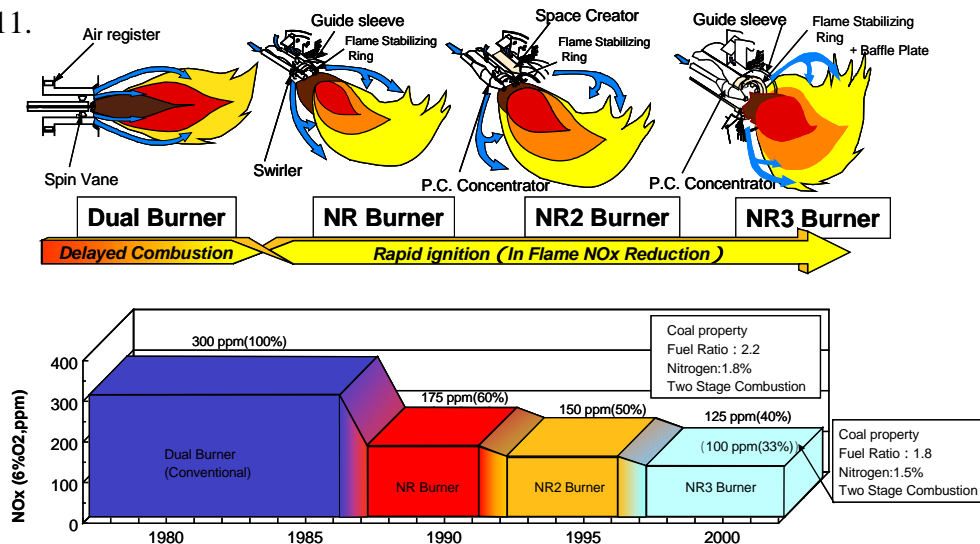


Fig. 11 Configuration of NR Series Burners together with Improvement Trend

These burners enable a low level of excess air at only 15% at economiser's outlet. This is important when firing any various kinds of imported coals.

## **6. Latest Boiler Experience**

The Tachibana-Wan Thermal Power Station No. 2 Unit (1,050MW) was completed for the Electric Power Development Co. Ltd. (EPDC) in December of 2000. It applies advanced steam temperatures of 25.0MPa and 600°C/ 610°C. The 3,000-t/h coal fired USC boiler for the generating plant was supplied by BHK, and during the commissioning and test period, it was confirmed the boiler attained all of its design performance specifications. To achieve these high-level steam parameters, newly developed high-strength materials were utilised in the high-temperature areas, and the latest combustion technology was used for environmental protection and also ensure a high level of efficiency, operating reliability and plant availability.

Subsequently, a 1000MW power plant (The Tokyo Electric Power Co. Inc. Japan, Hitachi-Naka Thermal Power Station No.1 boiler, 2870t/h steam output at Maximum continuous rating) is now under commissioning, and will provide the advanced steam condition, pressure 25.4MPa and temperatures 604°C/602°C.

### 6.1 Main Design Features of the Boilers

Fig. 12 is a cross-sectional schematic views of the Tachibana-Wan No.2 boiler and Hitachi-Naka No.1 boiler. As both boilers are medium-load plants burning coals with a wide range of grades, various factors were considered in designing the sliding-pressure boiler operation with advanced steam parameters. All these advanced plants burn a wide variety of world traded coals from Australia, Indonesia, South Africa etc. The main specification of the boilers is summarised in Table 3.

During the design engineering process of the Hitachi-Naka No.1 boiler, many special considerations were implemented to ensure improvement of operability, maintainability and reliability together with plant performance development. These efforts were synonymous with the activity for standardisation of the BHK BENSON Boiler such that targets are considered with the demands of power plant users.

As more types of coals are imported from overseas, achievement of this standardization can be easily transferred to meet world-wide operating requirements.

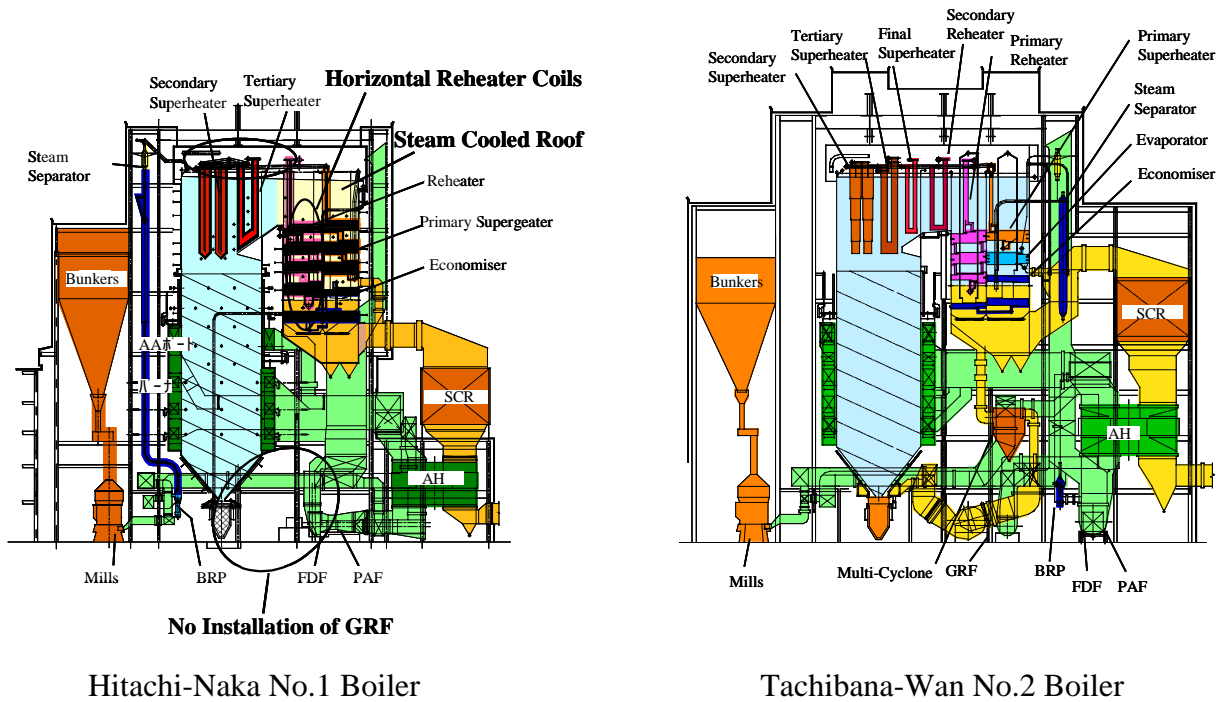


Fig. 12 Cross-Sectional Schematic Views

Table 3 Main Specification of Boilers

Item			Specification	
			Hitachi-Naka No.1	Tachibana-Wan No.2
Boiler Type			Babcock-Hitachi Supercritical Sliding Pressure Operation Benson Boiler	
MCR	Steam Flow	Main	2,870 t/h	3,000 t/h
		Reheat	2,407 t/h	2,490 t/h
	Steam Pressure	Main	25.4 MPa(g)	25.0 MPa(g)
		Reheat	604 °C	600 °C
Steam Temperature	Main	604 °C	600 °C	
	Reheat	602 °C	610 °C	
Economiser Inlet: Feedwater Temperature			286.9 °C	288 °C
Combustion System			Pulverised Coal Fired	
Draught System			Balanced Draught System	
Steam Temperature Control System		Main	Water-Fuel Ratio Control and Stage Attenuation	
		Reheat	Parallel Gas Dampering and Spray Attenuation	
Steam Temperature Control Range		Main	30% ECR to MCR	35% ECR to MCR
		Reheat	50% ECR to MCR	35% ECR to MCR

MCR: Maximum Continuous Rating,

ECR: Economical Continuous Rating

The principal design features are as follows:

- a) One of the best features of this Benson type boiler is the spirally wound water wall

arrangement at the lower furnace wall. In particular, Hitachi-Naka No.1 boiler equipped the mixing manifolds at the outlet of spiral water wall to ensure a more uniform metal temperature particularly at lower load conditions.

- b) The boiler and furnace walls are suspended from overhead steel work such that the progressive expansion of pressure parts is in a downward direction and there are no relative expansion effects experienced between the furnace wall sections. The furnace walls compose an all-welded membrane construction, which ensures complete gas tightness, and less in erection time at site.
- c) The combustion gas flows upward from the furnace area then turns into the pendant convection pass section where pendant surfaces are located to efficiently absorb heat from the hot gas. The gas then continues to flow down through the rear horizontal convection pass area.
- d) The primary superheaters and reheaters are located in a parallel and horizontal convection pass arrangement together with the economizers. This also enables a sufficient amount of reheater heating surface to be installed in this zone to permit allow quick responses for steam temperature control by a gas biasing system. To improve this effect, all reheater-heating surfaces are positioned in the horizontal convection.
- e) A steam/water separator is used during the start-up and shutdown, and at loads lower than minimum once-through load for smooth and reliable operation. In the case of Hitachi-Naka No.1 boiler, the steam separator is positioned at the boiler front side. With this arrangement, the all roof and cage walls are of steam-cooled surface and designed to mitigate the potential of excessive temperature deviations within panels.

## 6.2 Achievements in the Commissioning

Hitachi-Naka No.1 boiler is currently at the commissioning stage [early 2003], however, Tachibana-Wan No.2 boiler successfully entered commercial operation in December 2000. Stable and reliable operation with the advanced steam conditions has been confirmed in both static and dynamic

modes. The main features of boiler performance have also been confirmed and are described below.

Boiler Performance

Fig. 13 shows the steam-water characteristics at each turbine load. The main steam and reheat steam temperatures achieved anticipated values without causing any concerns. The backend gas temperature and amounts of excess air and unburned carbon in ash (UBC) were significantly below the design values. The boiler efficiency was found satisfactory across the load range.

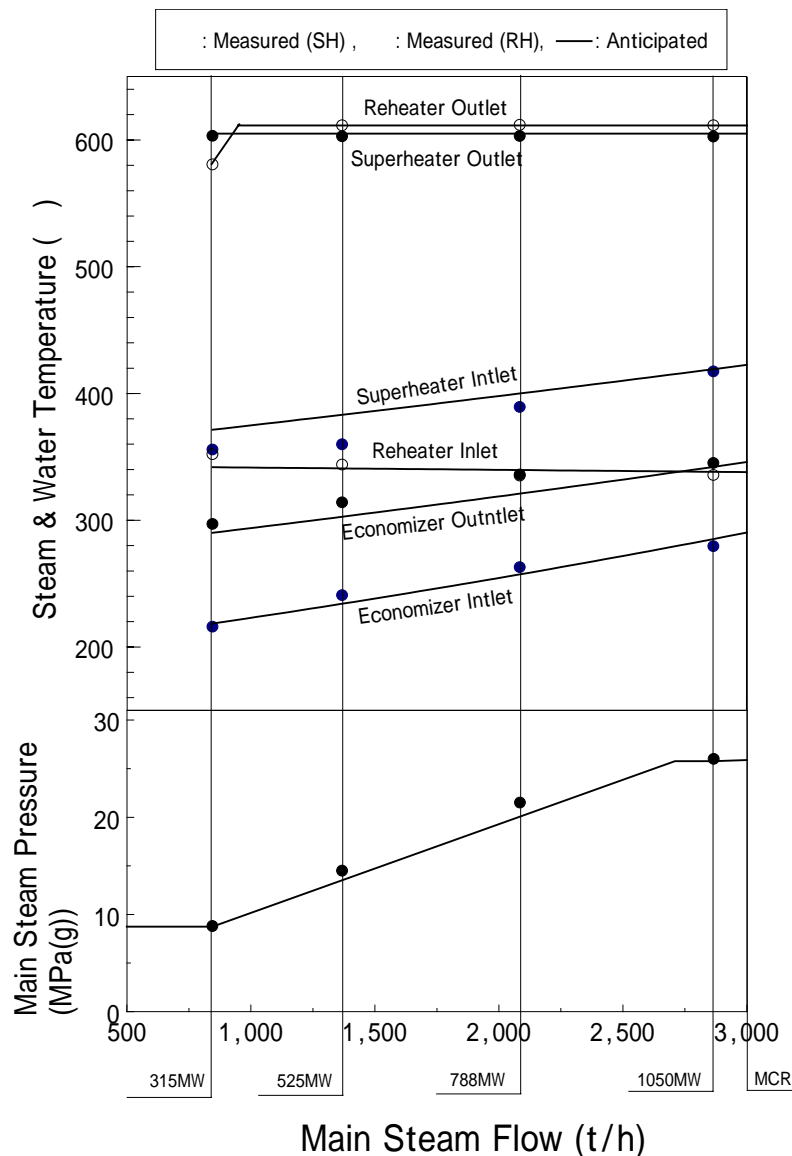


Fig. 13 Steam and Water Temperature and Main Steam Pressure Characteristics

Combustion Performance

The results of combustion testing are summarised in Fig. 14. The A-type coal has a high fuel ratio

(fixed carbon to volatile matter = 2:1) and nitrogen content, which means that the simultaneous reduction of NO<sub>x</sub> and UBC is extremely difficult. In burning the A-type coal, the reduction in UBC was confirmed, as were lower NO<sub>x</sub> emission levels. The same trend held when burning the B-type coal, with its higher fuel ratio (=2.4) and nitrogen. Fig. 15 shows the flame during burning of B-type coal at a load of 35% ECR (368MW). A very bright and stable flame was maintained at the tip of the fuel nozzle at the low coal-firing load of 35% of ECR, along with stable boiler performance.

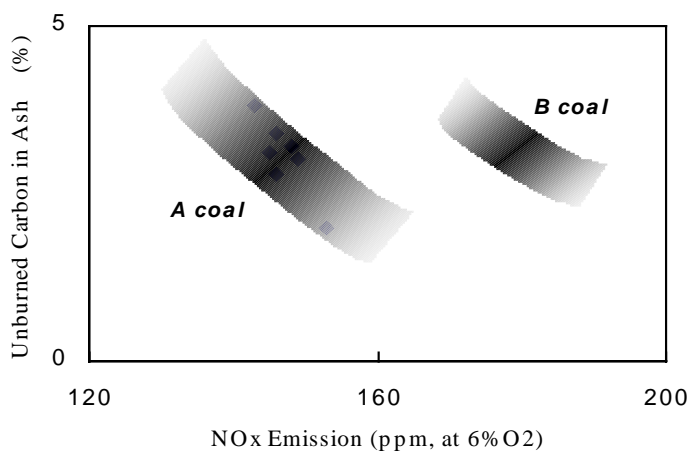


Fig. 14 Combustion Test Results at Rated Load



Fig. 15 Flame of Hitachi NR2 Burner

## 7. Application to Overseas Projects

There are several coal fired generating plant projects proceeding overseas with more projects entering the final contact stage. The current precedent project is the Genesee Power Generating Station Phase 3 boiler being provided for EPCOR in Canada (for 495MW Power Plant) and this project is now entering the peak of construction stage [spring 2003].

For the Genesee Power Generating Station Phase 3 boiler, the same design of BHK reference boiler, Nanao-Ohta No.1 boiler of Hokuriku Electric Power Co. (for 500MW Power Plant), was adopted. This was due to not only the similar design steam condition required but also that Nanao-Ohta No.1 boiler has achieved excellent availability records. To be able to apply the same proven design characteristics from the Nanao-Ohta No.1 boiler with modification was greatly appreciated by the client.

The reference plant, Nanao-Ohta No.1 boiler, is summarised in Fig. 16 and its specification is described in Table 4. Fig, together with the specification of Genesee Power Generation Station Phase 3 boiler. Fig. 17 indicating which design considerations were applied from the design of Nanao-Ohta No.1 boiler to Genesee Power Generating Station Phase 3 boiler.

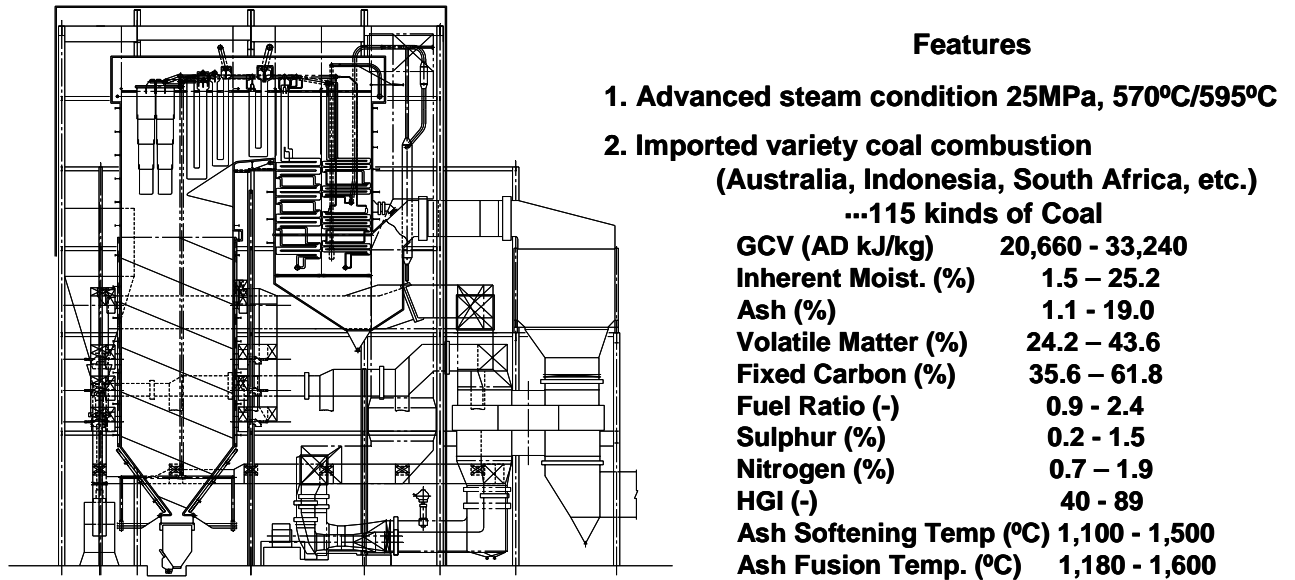


Fig. 16 Main Future of Nanao-Ohta No.1 boiler

Table 4 Main Specifications of Nanao-Ohta No.1 and Genesee No. 3 Boiler

Item			Specification	
			Nanao-Ota No.1	Genesee No. 3
Boiler Type			Babcock-Hitachi Supercritical Sliding Pressure Operation Benson Boiler	
MCR	Steam Flow	Main	1,510 t/h	1,450 t/h
		Reheat	1,158 t/h	1,192 t/h
	Steam Pressure	Main	25.0 MPa(g)	25.0 MPa(g)
		Reheat	570 °C	570 °C
	Economiser Inlet: Feedwater Temperature		289 °C	284 °C
Combustion System			Pulverised Coal Fired	
Draught System			Balanced Draught System	
Steam Temperature Control System		Main	Water-Fuel Ratio Control and Stage Attenuation	
		Reheat	Parallel Gas Dampering and Spray Attenuation	
Steam Temperature Control Range		Main	28% MCR to MCR	35% ECR to MCR
		Reheat	50% ECR to MCR	50% ECR to MCR

MCR: Maximum Continuous Rating,

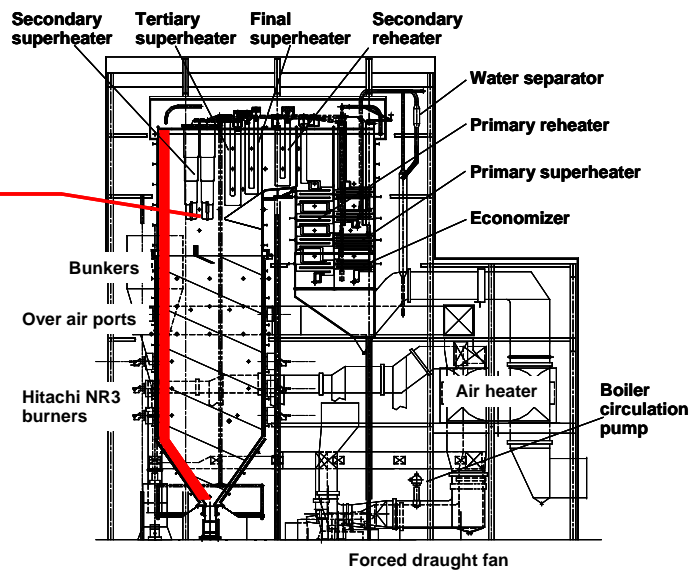
ECR: Economical Continuous Rating

**High Reliability 500mw Class  
Standard Design Philosophy  
Based On 7 Years Successful  
Operation Of Nanao Ota #2**

**Standard 500MW Class Boiler**

- Expanded Furnace Plane Area and Volume by +2m of depth to meet Genesee coal characteristics
- Reliable Design Philosophy confirmed from 7 years successful operation of Nanao-Ota boiler.

	Nanao-Ota 500MW	Genesee #3
Width	16.6 m	16.6 m
Depth	13.3 m	15.3 m
Height	53.6 m	55.1 m
Plant Area	220 m <sup>2</sup>	254 m <sup>2</sup>
Volume	10240 m <sup>3</sup>	12070 m <sup>3</sup>



**CANADA EPCOR Genesee 3**

Fig. 17 Design Considerations Applied to Genesee Power Generating Station Phase 3 Boiler

Another overseas project, Council Bluffs Energy Centre No.3 Boiler for MidAmerican Energy Company in USA (for 790MW Power Plant), is presently at the detailed engineering stage. Special consideration will take into account the coal properties applying to Powder River Basin (PRB), which can provide severe slagging in the boiler furnace. To cope with this undesirable coal property, the furnace design is required to accommodate sufficiently large sectional area. The Standard design established for Hitachi –Naka No.1 Boiler will therefore be fully applied to Council Bluffs Energy Centre No.3 Boiler. Fig. 18 shows cross-sectional schematic views of the Council Bluffs Energy Centre No.3 Boiler.

Boiler Type	Babcock-Hitachi Supercritical Sliding Pressure Operation Benson Boiler
MCR Steam Flow	2,531 t/h
Plant Capacity	790 MW (Net)
Steam Condition	25.3 MPa(g)/566 /593

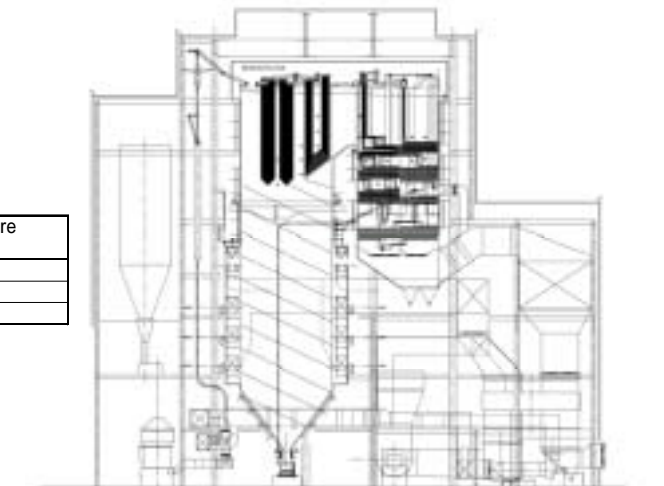


Fig. 18 Council Bluffs Energy Centre No.3 Boiler

## 8. Summary

Utility capacity and steam conditions have rapidly increased in Japan, to meet the demand for high efficiency and low emission pollution in generating plant. To cope with these demands, the BHK Benson technology has been and continues to be improved.

As evidence of this improvement, Tachibana-Wan No. 2 boiler with the advanced steam condition of 25.0MPa/ 600°C/ 610°C entered service in December of 2000. It was confirmed that this latest model coal fired boiler, which was designed to operate satisfactory with a wide range of coal fuels and to have improved countermeasures against environmental pollution, achieved all performance design specifications during its commissioning and testing period.

Consequently, Hitachi-Naka No. 1 Boiler with advanced steam condition of 25.4MPa/ 604°C/ 602°C is under construction. In this boiler unit, many special considerations have been implemented to improve operability, maintainability and reliability together with performance development and these innovative design features will be applied to future overseas projects.

BHK will continue to research and add improvements in performance and technology as their contribution to global welfare in the form of better technologies for energy and environmental systems.

## References

- 1) T.C.McGough, J.V.Pigford, P.A.Lafferty, S.Tomasevich et al.: Selection and Fabrication of Replacement Main Steam Piping for the Eddystone No. 1 Supercritical Pressure Unit, *Welding Journal*, Vol.64, No.1 (1985) pp.29-36.
- 2) K.Sakai, S.Morita : The design of a 1000MW coal-fired boiler with the advanced steam conditions of 593°C/593°C, *International Conference on Advanced Steam Plant, IMechE Conference Transaction 1997-2*, (21-22 May 1997) pp.155-167.
- 3) S. Morita et al., “ Development of Extremely Low NO<sub>x</sub> Pulverized Coal Burners by Using the Concept of ‘in-Flame’ NO<sub>x</sub> Reduction,” *ICOPE-93*, Vol. 2, pp. 325-330 (1993)