LIGNITE COAL FIRED POWER PLANT

TARSISIUS KRISTYADI

penerbit itenas

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Oleh

Tarsisius Kristyadi

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Penulis:
Tarsisius Kristyadi

Penyunting dan Penata Letak:
Tim Penerbit Itenas

Desain Sampul:
Agus Wardana

Diterbitkan oleh:
Penerbit Itenas
Jl. PKH. Mustapha No.23 Bandung 4012
Telpon. +62 22 7272215, Fax. +62 22 7202892
Email: penerbit@itenas.ac.id
Website: http://penerbit.itenas.ac.id/

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Preface

Indonesia has abundant low quality coal potential. Low quality coal is currently a concern because high and medium quality coal is running low. The use of low quality coal for power generation in Indonesia is currently being promoted. Technically, the use of low quality coal requires separate efforts. Several efforts to utilize low quality coal include gasification, mixing, drying or liquification.

This book presents the technology for utilizing low quality coal for steam power plants. Combustion technology is described in this book. In addition, it also explains the aspects that support low quality coal-based steam power plants.

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Author

Tarsisius Kristyadi

Content

1 INDONESIA COAL SOURCE

1.1 Coal Description

Coal is characterized by its use as either steam coal or metallurgical coal. Steam coal is used for electricity generators and for industrial facilities to produce steam, electricity or both. Metallurgical coal is usually refined into coking coal principally used to produce coke. There are four types of coal by geological composition: lignite, sub-bituminous, bituminous and anthracite. Each has characteristics that make it more or less suitable for different uses. Energy content and sulfur content are the most important coal characteristics and are used to determine the best use of particular types of coal, as well as to determine the price of different quality. Nearly B0 percent of Indonesian coal production is ranked as sub-bituminous with caloric values of between 5,100 and 6,100 kcal/kgl). Indonesian coal has a niche position in domestic and international markets where demand for environmentally friendly, low ash, low sulfur and low nitrogen, thermal coal is on the rise. The availability of domestic coal resources and reserve are listed in Table 1.1 shown below

Table 1.1 Coal Resources and Reserves (in million tons)

Quality (based on calorific value)	Resources					Percentage (%)	Reserve	
	Hypothetic	Inferred	Indicated	Measured	Total		Probable	Proven
Low (< 5100 kcal/kg)	5,057.68	6,586.19	3,721.16	5,815.96	21,180.99	20.18	6,704.02	1,358.40
Medium (5100-6100 kcal/kg)	27,772.26	18,961.08	11,007.87	11,994.88	69,736.09	66.45	5,871.17	2,718.41
High (6100-7100 kcal/kg)	1,695.39	6,172.71	1,063.25	4,039.61	12,970.96	12.36	829.18	1,326.90
Very High (> 7100 kcal/kg)	102.90	497.63	11.84	439.81	1,052.18	1.00	73.29	125.72
Total	**34,628.23**	**32,217.61**	**15,804.12**	**22,290.26**	**104,940.22**	**100**	**13,477.66**	**5,529.43**

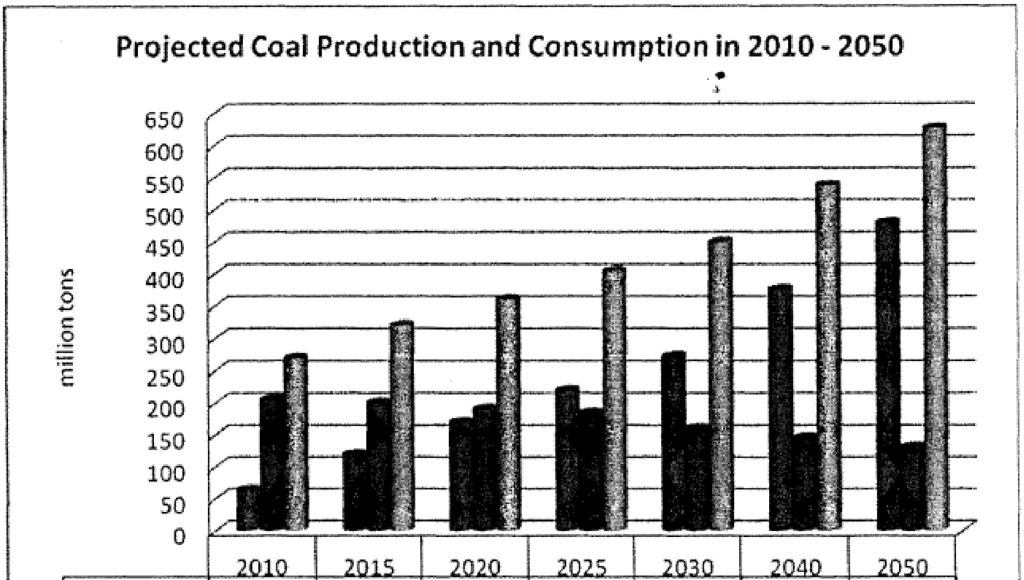
Source: Geological Agency of ESDM, 2009

Hypothetic; Undiscovered Coal Resources in beds that may reasonably be expected to exist in known mining districts under known geologic conditions. In general, Hypothetical Resources are in broad areas of coal fields where points of observation are absent and evidence is from distant outcrops, drill holes, or wells. Exploration that confirms their existence and reveals quantity and quality will permit their reclassification as a Reserve or ldentified Sub-economic Resource. lnferred: Coal in unexplored extensions of Demonstrated Resources for which estimates of the quality and size are based on geologic evidence and projection. Indicated: Coal for which estimates of the rank, quality, and quantity has been computed partly from sample analyses and measurements and partly from reasonable geologic projections

Measured: Coal for which estimates of the rank, quality, and quantity has been computed, within a margin of error of less than 20 percent, from sample analyses and measurements from closely spaced and geologically well-known sample sites. Resources: Concentrations of coal in such forms that economic extraction is currentlv or mav become feasible

1.2 Indonesia Coal Comsumption

Projections of National Demand for Coal PLN's coal demand is expected to further increase to 59 million tons in 2011, as more power plants under the first phase of the program will start operating. lt is projected to reach 120 million tons in 2015, of around 95.3 million tons will be used by electricity sector. : Coal production in 2009 was 254 thousand ton. ln 2009 Indonesia exported coal for about 198 thousand ton, while for domestic needs reached 56 thousand ton or about 22 % of national production used for domestic needs. Electricity sector absorbs some 65 percent of domesticoal consumption. After the issuing of UU 4/99 about Mineral and Coal Mining, emphasizing about obligation to fulfilldomestic coal needs or is called as Domestic Market Obligation (DMO) is firmly stated in article 5 verse (1) UU that "for national needs, the government after consulting with lndonesia Legislative Assembly (DPR) could determine policy of Mineral Priority and/or coal for national needs". This regulation is also stated in article 84 verse (1) Government Regulation No 2312010 that "The IUP (Mining License) holders of Production Operation and IUPK Production Operation has to emphasize mineral needs and/or coal for national needs." This DMO mechanism is reinforced more and more in Ministry Regulation No 34/2009 about Emphasizing of Mineral and Coal Need Supply for National Needs. Besides, every year the government issues Minister Decree which is about determination of minimal needs and percentage of coal sale for national needs.3) Therefore, although coal demand is increasing, the coal availability in the domestic market is still enough. In order to fulfill coal needs for its power plant, PLN has awarded coal supply contracts to several coal miners. Projections ofcoal production in 2050 are 628 million tons of which 131.6 million tons for export and 480 million tons for domestic need. lt is projected to reach 628 million tons in 2050, of around 376 million tons will be used by electricity sector. The data of projected production and estimation of domestic need from 2010 to 2050 can be seen in Figure 1.1.



	2010	2015	2020	2025	2030	2040	2050
Domestic	64	120	170	220	272.8	376.4	480
Export	206	201	191	185	160.96	146.28	131.6
Production	270	321	361	405	450	539	628

Source: *) Processed from Indonesian Coal Book 2010/2011 (Ministry of Energy and Mineral Resources)

Figure 1. 1 Projected Coal Productions and Consumption in 2010 – 2050

1.3 Indonesia Coal Price

The price of coal is primarily influenced by prevailing supply and demand and market outlook. In addition, different qualities of thermal coal have different energy content, sulfur content and ash content, affecting the price of internationally traded coal. Ocean freight costs also influence coal demand, with coal suppliers closer to end-user being preferred. The pricing of coal is complex since the price of a shipment of coal is based on the coal type (for instance, steam, coking or metallurgical), net calorific value and the content level of impurities, such as sulfur and ash. Higher quality coal generally attracts higher selling price

Coal is typically sold under long-term contracts that set the price of coal over the term of the contract, usually with an escalator based on inflation. There is a well-established world spot market for coal that is the source for most quoted spot prices. The FOB price of steam coal in international trade, as quoted by Bloomberg, increased from US$23.20 per ton in June 2000 to US$96.10 per ton in June 2010. In Indonesia, the government issues a monthly average coal prices reference, namely lndonesian Coal Price Reference (ICPR), and circulated to local governments as a reference for all coal mining companies in Indonesia. ICPR refers to four international/domestic publications of coal price, that is Indonesia Coal lndex (lCl-1), Platts-1, New Castle Global Coal Index (GC), based on coal with GCV (GAR) ol

6,322 kcal/kg, total moisture (arb) of 8.0 percent, total sulphuric content of 0.8 percent, ash content of 15 percent and FOB vessel 1). Based on Regulation of Directorate General of Minerals and Coal No 515.Kl32lDJBl2011 regarding Reference of Coal Benchmark Price Formula or "Harga Patokan Batubara" ("HPB'), the definition of Reference Coal Price or "Harga batubara Acuan" ("HBA") is average price from coal price index on previous month. And HPB is coal benchmark price for steam (thermal) coal and coking (metallurgical) coal as shown on Table 1.2

Table 1-2 Reference Coal Price

HBA (US$/Ton)	118.24	FOB Vessel

NO	BRAND	TYPICAL QUALITY				HPB MARKER (US$/ton)
		Calorific Value (kcal/kg GAR)	TM (%, ar)	TS (%, ar)	Ash (%,ar)	
	Batubara Utama					
1	Gunung Bayan I	7,000	10.0	1.0	15.0	127.27
2	Prima Coal	6,700	12.0	0.6	5.0	124.66
3	Pinang 6150	6,200	14.5	0.6	5.5	112.37
4	Indominco IM_East	5,700	17.5	1.6	4.8	96.36
5	Melawan Coal	5,400	22.5	0.4	5.0	90.68
6	Envirocoal	5,000	26.0	0.1	1.2	83.54
7	Jorong J-1	4,400	32.0	0.3	4.2	67.37
8	Ecocoal	4,200	35.0	0.2	3.9	61.04

Source: Directorate General of Minerals and Coal official website (www.esdm.go.id)

1.4 Coal Source

Jambi

Domestic Coal Producers Jambi Coal in Jambi is found in Sarolangun, Muarabulian, Muara Bungo and Tanjung Lubuk. Geographically, coal in this province exist in central part of the region, primarily in the southeast part which borders south sumatra province. Geologically, coal sediment in this region is located in South Sumatra basin, contained in Air Benakat and Mua6a Enim formation of Neogen age

Riau

Coal in Riau Province is found in Seberida, Cerenti, Rokan, Lubuk Jambi, Sungai Sulak, Ujung Batu and Kuantan Mudik areas. These areas belong to the regencies of Indragiri Hulu and Kampar, stretching over the western part of Rengat and pekanbaru. Geologiacally, deposits in these areas are found in Central Sumatera basin, contained in Sihapas and Kerinci Formation of paleocene aqe.

South Sumatra

South Sumatra province is spread in almost all areas, particularly Tanjung enim, Merapi, Selero, arahan, Banjarsari, Sungai Lilin, Bayungglencir, Baturaja, Muara Lakitan, Sungai Pinang, Sungai Malam, Babat Toman, Kluang, etc. Coal deposits in this province are located in the South Sumatra basin, associated with the Muara Enim Formation of Neogene Age.

West Kalimantan

West Kalimantan Coal deposits in West Kalimantan province are identified in the Sungai Tabun, Merakai, Bunut, Senaning, Sungai Empanang and Sungai Ambawang areas of the Sanggau, Sintang and Kapuas Hulu regencies. The coal deposits are formed in the K$ungau !]tir::;- 2008 : 2009 PT Tambang Batubara Bukit Asam Tbk 10.549 12.339 12.175 Basin within the Palaeogene Kantu Formation and the Neogene Ketunga

East Kalimantan

East Kalimantan Coal deposits in East Kalimantan province are scattered in the regencies of Pasir, Kutai kartanegara, Kutai Timur, Berau, Bulungan, Nunukan, Malinau and Kutai Barat and Samarinda. The coal deposits occur in the Kutai and Tarakan basins as seams within claystone, siltstone, and sand stone

Central Kalimantan

Central Kalimantan Coal deposits in Central Kalimantan province are located in Pendreh, Benangin, Lahai, Pangkalanbun, Kualakurun and Purukcahu, in the Barito Utara, Barito Selatan and Kotawaringin Barat regencies. Coal occurs in the Barito Basin associated with the Formations of Tanjung, Purukcahu, Batuayau, Warukin and Dahor, as intercalations in claystone, siltstone and quartz sandstone.

South Kalimantan

South Kalimantan is one of the country's biggest producers of coal. Coal deposits in this province are found in Tanjung, Barabai, Kandangan, Rantau, Satui, Sarongga, Mangkalapi, Pulau Laut and Pulau Sebuku, which are parts of the regencies of Tabalong, Hulu Sungai Utara, Hulu Sungai Tengah, Hulu Sungai Selatan, Kotabaru, Banjar and Tanah Laut. Geologically, coal deposits occur in the Barito basin and AsemAsem subbasin

2 INDONESIA COAL REGULATION

Coal mining business in Indonesia is regulated in the following regulations

- Law of the republic of indonesia number 3 of 2020 regarding amendment to law number 4 of 2009 regarding mineral and coal mining
- Minister of energy and mineral resources regulation number: 25 year 2018 regarding mineral and coal mining business
- Regulation of the minister of energy and mineral resources number: 26 year 2018 concerning implementation of good mining private and supervision of mineral and coal mining
- Minister of energy and mineral resources decree number: 1827 k/30/mem/2018 concerning guidelines for implementing good mining engineering principles
- Minister of energy and mineral resources decree number: 1798 k/30/mem/2018 regarding guidelines for the implementation of the preparation, determination and granting of mining business permits and special mining business area license
- Minister of energy and mineral resources decree number: 1796 k/30/mem/2018 concerning guidelines for application, evaluation and issuance of license in the mineral and coal mining field
- Decree of the minister of energy and mineral resources number: 1095 k/30/mem/2014 concerning determination of sumatera island mining area
- Minister of energy and mineral resources decree number 48/2017 Supervision of Business in the Energy and Natural Resources Sector
- Minister of energy and mineral resources decree number 25/2015 Delegation of PTSP Licensing
- Minister of energy and mineral resources decree number 32/2015 Minerba Special Permit
- Minister of energy and mineral resources decree number 33/2015 Boundary Signs of WIUP /K
- Minister of energy and mineral resources decree number 42/2016 Minerba Competency Standardization
- Minister of energy and mineral resources decree number 43/2015 Evaluation of IUP Issuance
- Minister of energy and mineral resources decree number 9/2016
- Minister of energy and mineral resources decree number 24/2016 Mine Mouth PL Coal Price
- Minister of energy and mineral resources decree number 5/2017 Increasing Value Added of Domestic Minerals
- Minister of energy and mineral resources decree number 6/2017 Procedures for Export Recommendations

- Minister of energy and mineral resources decree number 9/2017 Procedure for Divestment of Mineral and Coal Shares
- Minister of energy and mineral resources decree number 15/2017 Provision & Price of Coal for Mine Mouth Generators

Market Regulation for Indonesian Coal The following regulations regarding market regulations emphasize about Domestic Market Obligation: for lndonesia Coal which 1. UU 4/2009 about Mineral and Coal Mining 2. Government Regulation No 2312010 3. Minister of Energy and Mineral Resources Regulation No 34/2009 After the issuing of UU 412009 about Mineral and Coal Mining, emphasizing about obligation to fulfill domestic coal needs or is called as Domestic Market Obligation (DMO) is firmly stated in article 5 verse (1) UU that "for national needs, the government after consulting with Indonesia Legislative Assembly (DPR) could determine policy of Mineral Priority and/or coal for national needs". This regulation is also stated in article 84 verse (1) Government Regulation No 2312010 that "The IUP (Mining License) holders of Production Operation and IUPK Production Operation has to emphasize mineral needs and/or coal for national needs." This DMO mechanism is reinforced more and more in Minister of Energy and Mineral Resources Regulation No 34/2009 about Emphasizing of Mineral and Coal Need Supply for National Needs. Besides, every year the government issues Minister Decree which is about determination ofminimal needs and percentage of coal sale for national needs.3) Therefore, although coal demand is increasing, the domestic coal needs will be fulfilled. Moreover in order to fulfill coal needs for its power plant, PLN has awarded coal supply contracts to several coal miners.

3 LIGNITE COAL CHARACTERISTIC

In the classification of coal, in general this group is Coal with the lowest level of coalescence and brown in color or dark brown. The content of water and volatile matter is relatively high, and generally non-coking or non-caking. In international classification, This coal is defined as having a calorific value (ash free basis) of less than 5700 kcal/kg. Lignite, often referred to as brown coal, is a fuel a soft brown with characteristics considered to be of the lowest rank from coal, in Greece, Germany, Poland, Serbia, Russia, the United States, India, Australia and many other parts of Europe use almost lignite coal exclusively as a fuel for steam electric power generation. Until with 50% of the electricity from Greece and 24.6% from Germany coming from lignite power plant. Lignite coal is brown and has a carbon content about 25-35%, inherent high moisture content sometimes as high as 66%, and the ash content ranges from 6% to 19% in comparison with 6% to 12% for bituminous. Lignite has a high content of volatile matter which makes it more easy to convert into gas and liquid petroleum products from coal higher rank. However, high moisture content and susceptibility against spontaneous combustion can cause problems in transportation and storage. However, it is now known that efficient processes are eliminated latent moisture locked in the structure of brown coal will throw away the risk spontaneous combustion to the same extent as black coal, will converting the calorific value of brown coal to black coal equivalent fuel
while significantly reducing brown coals' compacted emission profile to the same level or better than most black coal.
Below is the typical lignite coal specification.

Table 3-1 Typical ppecification of Lignite Coal

PARAMETER ANALYSIS			
1	2	3	4
OPERATIONAL STATUS			
- MEASURED (MILLION TON)	393,37		
- RESERVED (MINEABLE) (MILLION TON)	367,08		
- SUPPLY CAPABILITY (MILLION TON/YEAR)			
	MINIMUM	**MAXIMUM**	**TYPICAL**
PROXIMATE ANALYSIS (% ar)			
Total Moisture	48,08	51,11	49,59
Inherent Moisture	17,39	18,65	18,02
Volatile Matter	22,46	23,65	23,09
Fixed Carbon	19,20	20,95	20,11
Ash Content	4,98	9,35	7,22
EQUILIBRIUM MOISTURE (%)			
MINERAL MATTER (%)			
SPECIFIC ENERGY			
Gross (kCal/kg adb)	4.281	4.803	4.542
Gross (kCal/kg ar)	2.633	2.953	2.793
Net (kCal/kg ar)	2.230	2.550	2.390
ULTIMATE ANALYSIS (% daf)			
Carbon	46,96	52,27	51,62
Hydrogen	3,37	3,73	3,65
Nitrogen	0,60	6,75	1,23
Sulphur	0,20	1,10	0,67
Oxygen	36,24	48,88	42,81
Chlorine	-	-	-
Total			99,98
SULPHUR (% adb)			
Pyritic			
Sulphate			
Organic			
Total	0,25	0,73	0,49
RELATIVE DENSITY (adb)	1,26	1,32	1,30
HARDGROVE GRINDABILITY INDEX	50	70	60

PARAMETER ANALYSIS	MINIMUM	MAXIMUM	TYPICAL
1	2	3	4
ABRASION INDEX			
ASH FUSION TEMPERATURE (°C)			
Oxidizing Atmosphere			
Deformation	1.050	1.170	1.150
Softening	1.032	1.261	1.236
Hemisphere	1.214	1.290	1.252
Flow	1.246	1.413	1.358
Reducing Atmosphere			
Deformation			-
Softening			-
Hemisphere			-
Flow			-
ANALYSIS OF ASH (% DB)			
Silica Oxide (SiO_2)	37,10	67,40	45,06
Alumunium Oxide (Al_2O_3)	7,40	34,50	25,02
Iron Oxide (Fe_2O_3)	4,15	12,64	8,75
Titanium Oxide (TiO_3)	0,57	0,99	0,87
Manganese Oxide (Mn_3O_4)	0,04	0,19	0,10
Magnesium Oxide (MgO)	1,40	4,40	2,77
Calcium Oxide (CaO)	1,50	8,40	6,37
Natrium Oxide (Na_2O)	0,34	5,30	3,50
Kalium Oxide (K_2O)	0,31	0,56	0,48
Phospate Peroxide (P_2O_5)	0,33	1,01	0,53
Sulphur Trioxide (SO_3)	3,13	8,96	6,84
Loss on Ignition or Undetermined			-
Total			100,29

4 LIGNITE COAL FIRED POWER PLANT STANDARD

Following parameter should be taken into account in lignite coal fired power plant.

Ambient conditions

Since Indoensia is near the Equator, the climate of the project site is tropical in nature, hot and humid. The climatic conditions are based on data from the Climatology Meteorology and Geophysics Agency (BMKG). Generally the air temperature ranges from 20.2°C up to 35°C, relative humidity ranged between 79 % until 88 %, maximum annual rainfall 2,894 mm, and maximum wind speed of 8 knots, with the dominant wind direction from North, South and South East.

Air temperature, humidity and pressure

The following table defines the site conditions, which shall be applied for the design of the power plant. As basis for the performance test guarantees, the average conditions were applied.

Table 4-1: Meteorological parameters

Parameter	Average	Min	Max
Ambient dry air temperature. ^{o}C	26.84	20.2	35
Atmospheric pressure, mbar	1,009.13	1,005.2	1,011.2
Relative humidity, %	84.39	79	88

Rainfall

The project site has dry season and wet season. The rainfall intensity varies between the seasons and the years. Highest rainfalls can normally be expected from October to April.

Table 4-2: Rainfall data

Parameter	Unit	Data
Maximum annual rainfall	mm	2,894
Maximum monthly rainfall	mm	563.4
Average annual rainfall	mm	2,291.27

Evaporation

The annual average evaporation is 56.31mm.

Wind conditions

The maximum wind velocity of 8 knots will be considered in the design.
The dominant wind direction are North, South and South East.

Seismic conditions

- Peak acceleration in bedrock (PGA): 0.10 – 0.15g
- Spectral response acceleration in 0.2 seconds in bedrock (SS): 0.20 – 0.25g
- Acceleration response spectra in 1 second in bedrock (S1): 0.10 – 0.15g
- Peak ground acceleration at the surface: 1.2g

Secondary fuel

Light fuel oil (LFO) will be used as auxiliary fuel for:

- start-up and supplementing firing at low load of the boiler
- auxiliary boiler
- emergency diesel generator
- diesel firefighting pump
- Vehicles (trucks, bulldozers, etc.)

The light oil No.2 to ASTM or its equivalences is recommended as the auxiliary fuel. This oil is abundantly available and has been widely used in coal-fired power plant. The indicative fuel analysis is given below.
The oil can be used as fuel for steam boiler as well as for combustion engines such as diesel generators or trucks.

Table 4-3: Indicative fuel oil analysis

Property	Unit	Guarantee	Limit	Test Method
Density at 15˚C	kg/m³	820-845		EN ISO 3675, EN ISO 12185
Polycyclic aromatic hydrocarbons	wt %	8	max	EN 12916
Flash point	˚C	55	min	EN 2719
Cold filter plugging point (CFPP)	˚C			EN 116
Winter Grade		-15	max	
Summer Grade		5	max	
Distillation				EN ISO 3405
Recovered at 250 ˚C	vol %	65	max	
Recovered at 350 ˚C	vol %	85	min	
95 %(vol/vol) recovered at	˚C	360	max	
Sulphur	mg/kg	10	max	EN ISO 20846
				EN ISO 20884
Carbon residue (on 10 % residue)	wt %	0.3	max	EN ISO 10370
Viscosity at 40 ˚C	cSt	2.0-4.5		EN ISO 3104

Property	Unit	Guarantee	Limit	Test Method
Copper strip corrosion(3h at 50^{o}C)	Rating	No.1	max	EN ISO 2160
Fatty acid methyl ester (FAME) content	vol %	7	max	EN 14078
Ash	wt %	0.01	max	EN ISO 6245
Cetane number		51	min	EN ISO 5165,EN 15195
Cetane index	Calc.	46	min	EN ISO 4264
Water	mg/kg	200	max	EN ISO 12937
Particulate matter	mg/kg	24	max	EN 12662
Oxidation stability	g/m³	25	max	EN ISO 12205
	µm	460	max	EN ISO12156-1

Lubricity, corrected (wsd1.4) at 60 ˚C

Solid and liquid residues

The following different residues have to be taken into account:

- Bottom ash from the boilers
- Fly ash from the ash hoppers below the economizer, the air preheaters and the dust filter (electrostatic precipitators or bag filter)
- Gypsum from FGD plant
- Sludge from waste water treatment
- Waste oil from oil separators

Ash quality

The following preliminary ash and gypsum qualities have been determined based on the performance coal with an NCV of 2,440 kcal/kg and the limestone analysis

Table 4-4: Indicative parameters of ash and gypsum

Fly ash parameter	Unit	Value
Unburned combustibles	weight %	5.0
Ash from fuel	weight %	95.0

Bottom ash parameter	Unit	Value
Unburned combustibles	weight %	2.5
Ash from fuel	weight %	97.5

Gypsum parameter	Unit	Value
Gypsum ($CaSO_4.2H_2O$)	weight %	82.5
Unreacted limestone	weight %	5.0

Gypsum parameter	Unit	Value
Other impurities	weight %	2.5
Moisture	weight %	10.0

Ash and gypsum utilization options

The fly ash can generally be used as component for the cement production, bottom ash can generally be used as a sub base material for road construction or for brick-making, while gypsum can be used as a material for production of plaster boards used in building industry. These materials could be sold to local cement plants, road construction companies or construction material companies. Further investigation is required to identify possible off-takers.

Sludge

Any sludge from the waste water treatment plant shall be disposed externally.

Waste oil

Waste oil from the oil separators shall be disposed of externally.

Operation regime and plant control

A fully automatic control shall be possible in the load range between 60% and 100% of the nominal load. Therefore, all components shall be designed in such a manner that they can be automatically operated by the control system under all ambient and all load conditions between 60 % load and full load.

There is no requirement for the plant to operate continuously above the manufacturer's declared maximum continuous rating ("MCR") at given ambient conditions and the physical condition. However, during emergency conditions, the plant output shall be increased to VWO conditions for a limited period.

It is anticipated that during early operating years the power plant will operate as a base load power generating station, generating close to the rated output for much of the time. In later years it is likely that it may be required to operate on a cycling basis and that it and its control system must be designed to maximize efficient operation, under both these operating regimes.

The control and monitoring of the plant shall be carried out in a central control room, from where the generators will normally be started, auto-synchronized, and initially loaded. The plant shall be designed to ensure that automatic hot, warm and cold starts, as well as shut downs, are achieved on a reliable basis throughout its design life.

The power plant will be normally frequency controlled rather than load controlled.

Plant availability and plant load factor

The plant shall be designed to achieve the levels of availability normally expected of modern ultrasupercritical coal fired power plants of the similar size, and as required by the PPA.

Lifetime

The design lifetime of the Project shall be 200,000 operating hours and 25 years, whichever is longer.

Grid code requirement

A preamble document provides the context for the Grid Code and its various sub-sections including definitions and abbreviations. The Jawa – Madura – Bali Grid Code 2007 covers the following Codes:

- Grid Management Code (GMC): This Code focuses on the general procedures regarding amendments/ revisions to the Grid Code, settlement of disputes, and periodic review of grid operation and management.
- Connecting Code (CC): This Code stipulates the minimum technical and operational requirements for the Grid Users (e.g. power plant operators), and the minimum technical and operational requirements to be fulfilled by transmission and load dispatch center at the connection points with the Grid Users.
- Operating Code (OC): This Code stipulates the prevailing regulations and procedures to ensure that the reliability and efficiency of the Jawa – Maruda – Bali grid system can be maintained at a certain level.
- Scheduling and Dispatching Code (SDC): This Code describes the regulation and procedures for the plant operators' transactions and allocation scheduling including long-term, monthly, weekly, daily schedules/ dispatch.
- Settlement Code (SC): This Code focuses on the regulation and procedures regarding invoice calculation and payment in energy sale and services.
- Metering Code (MC): This Code defines the minimum technical and operational requirement for transaction meters at the connection point.
- Data Requirement Code (DRC): This Code defines the obligations of parties with regard to the provision of information to the Load Dispatch Center, the extent and format of data to be submitted, and the protocols for submission of the required data.

Within the Grid Code most relevant are Connection Code and its appendices, and Metering Code.

The following list includes a brief excerpt of the technical requirements within the Grid Code; however it is the obligation of the Contractor to meet all necessary requirements as defined in the Grid Code.

Table 4-5: Grid code requirements

Grid Code Requirement		**Clause**	**Description**
CC 2.0	Characteristics of grid performance		
	System frequency	CC 2.1.a	Nominal frequency of 50Hz shall not be lower than 49.5Hz or higher than 50.5Hz; during emergency and interruption, the system frequency can be as low as 47.5Hz or as high as 52.0Hz before the generating unit is allowed to detach from the system.

Grid Code Requirement		Clause	Description
	System voltage	CC 2.1.b	The system voltage shall be maintained within +/-5% for nominal 500kV, +5%/-10% for nominal 150kV, 70kV and 20kV,
	Harmonic distortion	CC 2.1.c	At each connection point in normal operating condition and in planned and unplanned outage conditions, the total harmonic distortion shall be zero for nominal 500kV, not more than 3% for nominal 150kV, 70kV and 20kV.
	Negative sequence component of the phase voltage	CC 2.1.d	The negative sequence component of the phase voltage not higher than 1% in a normal operating condition and planned outage, not higher than 2% during infrequently short duration peaks.
	Voltage fluctuation at connection point	CC 2.1.e	Not higher than 2% of the voltage level for each recurrent step change. Each big voltage excursion occurrence outside the step change is allowed to 3% as long as it does not produce risks to the grid or the Grid Users' installations. A short flicker of 1.0 unit and 0.8 in a longer period measurable by a flicker meter is as per IEC 868 specifications.
	Power factor	CC 2.1.f	Minimum 0.85 lagging at the connection point.
	Energy quality meter	CC 2.1.g	Energy quality meter capable of continuous monitoring and recording the results on softcopies shall be installed.
CC 3.0	Grid User equipment requirements		
	General requirements	CC 3.1	Facilities connected to the Grid shall be operable under the conditions defined in CC 2.1 and meet the requirements from Appendix 1 to the Connecting Code.
	Rapid response frequency regulator	CC 3.2.1.a	Generating unit shall be equipped with a rapid response regulator that affects the primary control of the system

Grid Code Requirement		Clause	Description
			frequency between 48.5Hz and 51.0Hz. The genset shall be capable of receiving the AGC signals from the load dispatch center to allow secondary control of system frequency.
	Rapid response automatic voltage governing device	CC 3.2.1.b	Generating unit shall be equipped with a rapid response automatic voltage governing device for governing the voltage of the generator terminal.
	Power system stabilizer	CC 3.2.1.c	Generating unit shall be equipped with a power system stabilizer.
	Range of frequency	CC 3.2.4	Generating unit shall be capable of operating in the declared capacity at the frequency in a span from 49.0Hz to 51.0Hz, at each power factor between 0.85 lagging and 0.9 leading.

Emission limits

Flue gas emissions

The concentration of pollutants at the outlet of the stack shall not exceed the limit stipulated by the Environment Authority of Indonesia, and in the event of the project being financed by an international financing institution the limit suggested by them which normally is in accordance with the World Bank/IFC Guidelines.

Following are maximum allowable emissions according to the Indonesian emission standard and World Bank /IFC guideline (Environmental, Health, and Safety Guidelines Thermal Power Plants, 2008, Table 6 (c)):

Table 4-6 : Flue gas emission limits

Parameter	Unit	Indonesian Standard(*)	WB/IFC Guidelines(**)
SO2	mg/Nm^3	750	850
NO_x	mg/Nm^3	750	510
Particulate matter (PM)	mg/Nm^3	100	50

(*) at dry and 7%O2 condition, in accordance with MoE Regulation No.21 Year 2008; (**) at dry and 6% O2 condition.

Air quality limits (Ground level concentrations of pollutants)

The concentration of pollutants at any locations at the ground level shall not exceed the limit stipulated in the National Ambient Air Quality Standard (NAAQS) of Indonesia, and in the event of the project being financed by an international financing institution the limit suggested by them which normally is in accordance with the World Bank/ IFC Guidelines.

Following are the maximum allowable ground level concentrations in compliance with the NAAQS and World Bank /IFC guideline (General IFS Environmental, Health, and Safety Guidelines Thermal Power Plants, 2008, Table 1.1.1: WHO Ambient Air Quality Guidelines):

Table 4-7: Air quality limits

Parameter	**Period**	**Unit**	**Indonesia (NAAQS)**	**WB/IFC WHO**
Particulate matter (PM_{10})	24 hour	$\mu g/m^3$	150	50
	1 year	$\mu g/m^3$	---	20
SO_2	1 hour	$\mu g/m^3$	900	---
	24 hour	$\mu g/m^3$	365	20
	1 year	$\mu g/m^3$	60	---
	10 minute	$\mu g/m^3$	---	500
NO_2	1 hour	$\mu g/m^3$	400	200
	24 hour	$\mu g/m^3$	150	---
	1 year	$\mu g/m^3$	100	40
Ozone	1 hour	$\mu g/m^3$	235	---
	8 hour	$\mu g/m^3$	---	100
	1 year	$\mu g/m^3$	50	---
CO	1 hour	$\mu g/m^3$	30,000	30,000
	8 hour	$\mu g/m^3$	---	10,000
	24 year	$\mu g/m^3$	10,000	---

Effluent emissions

Industrial effluent limits

Following maximum allowable discharge limits according to the Indonesian Effluent Standard (MoE Regulation No.08 Year 2009), and in the event of the project being financed in whole or in part by an international finance institution World Bank /IFC guideline (Environmental, Health, and Safety Guidelines Thermal Power Plants, 2008, Table 5), shall not be exceeded.

Note that the Indonesian effluent standard provides different limits for main process wastewaters, supporting activity wastewaters, and oily wastewater. The effluent limits according to the Indonesian Effluent Standard in Table 4-8 are based on an assumption that wastewater from any sources within the plant, except sanitary sewage, are collected to a common reservoir in the wastewater treatment system and then treated and discharged, so that there will be only one effluent stream.

Table 4-8: Industrial effluent limits

Parameter	Unit	Indonesian Standard	World Bank/ IFC
pH	-	6 – 9	6 – 9
Total suspended solids (TSS)	mg/l	100	50
Oil & grease	mg/l	10	10
Total residual chlorine	mg/l	0.5	0.2
Chromium, total	mg/l	0.5	0.5
Manganese	mg/l	2.0	---
Copper	mg/l	1.0	0.5
Iron	mg/l	3.0	1.0
Zinc	mg/l	1.0	1.0
Lead	mg/l	---	0.5
Cadmium	mg/l	---	0.1
Mercury	mg/l	---	0.005
Arsenic	mg/l	---	0.5
Phosphate (PO_4^{3-})	mg/l	10	---
COD	mg/l	300	---
TOC	mg/l	110	---

Sanitary sewage discharge limits

Following maximum allowable discharge limits according to the Indonesian effluent standard, and in the event of the project being financed by an international finance institution WHO Health guidelines for the safe use of waste water in agriculture with light to moderate restriction on use, shall not be exceeded.

Table 4-9: Sanitary sewage discharge limits

Parameter	Unit	Indonesian Standard	WHO Guidelines
pH	-	---	6.5 – 9
Total dissolved solids (TDS)	mg/l	---	< 2,000
Sodium	mg/l	---	< 9
Chloride	mg/l	---	< 10
Total residual chlorine	mg/l	---	< 5
Hydrogen sulfide	mg/l	---	< 2
Total nitrogen	mg/l	---	< 300
Total suspended solids (TSS)	mg/l	---	< 100

Noise immission limits

According to World Bank /IFC guideline (General EHS Guidelines, 2008) noise impacts should not exceed the following levels at the nearest receptor location off-site:

Table 4-10 : Noise limits

Noise Level Guidelines (IFC, 2007)		
Receptor	**One Hour L_{Aeq} (dBA)**	
	Day-time 07:00 to 22:00	**Night-time 22:00 to 07:00**
Residential; institutional and educational receptors	55	45

The IFC guideline will also limit a maximum increase in background levels of 3 dB at the nearest receptor location off-site. However no relevant background noise pollution is expected at the selected Project Site.

Indoor noise levels
For acceptable indoor noise levels the WHO -guideline for certain rooms within the power plant buildings will be followed. Those values will be fixed in the technical specification.

Redundancy philosophy

The redundancy concept depends on the following main criteria:

- required plant availability
- availability/reliability of each component
- spare part philosophy to ensure limited outage times
- economic balance between investment, O&M costs and plant availability (i.e. higher investment is justified by lower generation costs)

The following general redundancy philosophy should be applied:

- Each equipment whose unavailability due to a failure could result in damages to another equipment shall be backed up by a stand-by equipment, one of them being fed by an emergency source in case of external black out.
- The outage of one component of an auxiliary system must not cause any limitation of the whole plant or any power unit operation
- Replacement and repair of redundant components shall be possible without interrupting plant operation
- If only 1 x 100% component is implemented – especially due to the outage of this component - should in the worst case cause only a short-term outage of the power plant unit. By appropriate stock keeping of spare components the outage times should be kept to a minimum.

Following redundancy concept has been laid down for the main components:
Boiler system (per unit):

- Forced draft fans: 2 x 50%
- Induced draft fans: 2 x 50%
- Mill s n-1

- Bottom ash crushers: 2 x 100%

Water steam cycle (per unit):
- Steam turbine generator: 1 x 100%
- Feedwater pumps: 3 x 50%
- Main condensate pumps: 2 x 100%

Cooling system (per unit):

- Condensate pumps: 2 x 100%
- Closed cooling water pumps: 2 x 100%

Coal handling system (per plant):
- Stacker 2 x 100%
- Reclaimer 2 x 100%
- Conveyor 2 x 100%
- Coal crusher 2 x 100%

Limestone handling system (per plant):
- Limestone crusher 2 x 100%
- Conveyor 2 x 100%

Fuel oil system (per plant):
- Pumps 4 x 33%

Water system (per plant):
- Demineralization plant: 2 x 100%
- Process pumps: 2 x 100%
- Effluent water pumps: 2 x 100%

Electric system (per unit):
- Main transformer: 1 x 100%
- Auxiliary transformer: 1 x 200%

5 LIGNITE COMBUSTION TECHNOLOGY

This chapter makes an investigation into the competing coal firing technologies, that is to say, PC (pulverized coal) and CFB (circulating fluidized bed). The BFB (bubbling fluidized bed) firing has a limitation in boiler capacity, while PCFB (pressurized circulating fluidized bed) and IGCC (integrated gasification combined cycle) have not been fully commercialized, so these technologies shall not be considered.

5.1 Pulverised Coal Combustion.

Conventional technology for thermal power generation from high moisture brown coals involves pulverised fuel combustion, where the coal is dried on-line in an integrated mill/drying system (Clark, 1985). In this technology, which was introduced to Victoria from Germany at Yallourn C and D stations in the 1950s, a large proportion (about 50%) of the hot exit flue gas is recycled via large off-take ducts to dry the as-mined coal in the integrated mill/drying/burner system.
Pulverized coal (PC) combustion is the most prevalent method utilized in coal-fired power plants and dates back to 1925, when the first PC plant was constructed. Currently, steam power stations fired with pulverized coal generate approximately 49% of the electricity in the U.S., based on the U.S. Department of Energy/Energy Information Administration (DOE/EIA) Electric Power Annual Report released in October 2007, and 80% in China. The current situation is not much different.

PC firing is a proven firing technology for various kinds of coal including lignite. PC boilers have been manufactured in a wide range of capacity from tens of megawatts to as large as more than 1,00MWe. The biggest PC boiler currently in operation is 1,300 MW, however, 300MW to 660 MW capacity PC units are the most popular in the world. Large capacity lignite-fired boilers are now available even at a capacity of 1,100MWe, at subcritical, supercritical and even ultrasupercritical steam conditions.

This basic technology, shown in Figure 5-1, has been applied to subsequent stations at Yallourn and Loy Yang. Morwell coal, with its lower moisture content (60% or 1.5 t water / t dry coal) and greater ease of ignition, does not require separation firing in the integrated mill/drying system used at Hazelwood Power Station.

Below are some references of lignite-fired thermal power plants worldwide:

Table 5-1 References of lignite-fired units

Name & Country	Operation	Capacity	Type	Moisture
Baicheng, China	2010	2x 660 MW	Lignite	
Huaneng Jiutai, China	2010	2x 670 MW	Lignite	
Schkopau, Germany	1995	2x450 MW	Lignite	>50%
Neurath, Germany	1976	3x312MW + 2x633MW	Lignite	>50%
Neurath F&G, Germany	2012	2x 1100 MW	Lignite	>50%
Niederaussem , Germany	1976	2x 600 MW	Lignite	>50%
Niederaussem K, Germany	2002	1x 1,000 MW	Lignite	>50%
Ledvice, Czech Republic	2012	1x660MW	Lignite	>50%
Belchatow II, Poland	2011	1x858 MW	Lignite	>50%
Patnow II, Poland	2011	1x460 MW	Lignite	>50%
Schwarze Pumpe, Germany		2x 800 MW	Lignite	>50%
Pirkey, Texas, USA	1985	1x721MW	Lignite	
Sandow 5, Texas, USA	2009	1x615MW	Lignite	
Sandow, Texas, USA	1981	1x591MW	Lignite	
Coal Creek Station, USA		2x600MW	Lignite	
Maritsa East 1, Bulgaria	2011	2x335MW	Lignite	
Maritsa East 2, Bulgaria	2010	2x360MW	Lignite	

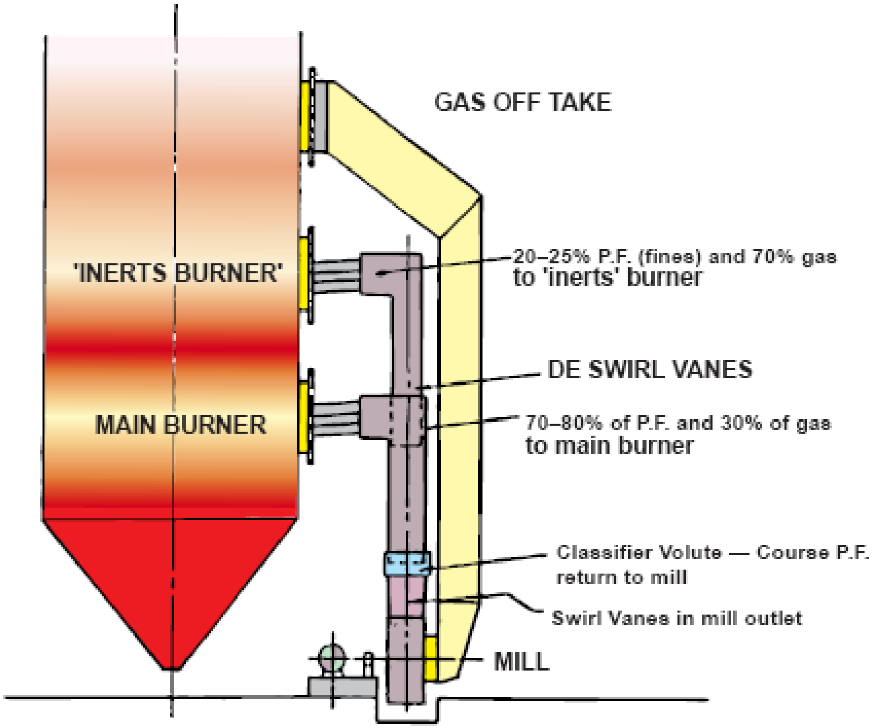


Figure 5-1 Typical Separation Firing System Developed for Victorian Brown Coal

Because of the high inert gas loading, furnace exit gas temperatures (~1200 ^{0}C) and flame temperatures are reduced, hence furnace exit gas temperature is lower and minimize superheater slagging and boiler back-pass fouling . The lower flame temperature has a beneficial effect in reducing nitrogen oxide emissions, but results in a very large and capital intensive plant compared with black coal units of similar capacity, as seen in Figure 5.2 [St Baker and Juniper, 1982].
In a conventional PC firing system, hot air at a temperature of more or less 300^{o}C from an air heater is used to dry coal in the mills and transport the pulverized coal into the furnace. Mills normally are of vertical spindle or horizontal tube type.

Conventional PC firing systems normally are used when the moisture content of coal is below around 30%, as with anthracite and bituminous coals. Higher moisture coals cannot be efficiently ground and dried, which results in, among other adverse outcomes, poor ignition condition and unstable and incomplete combustion.

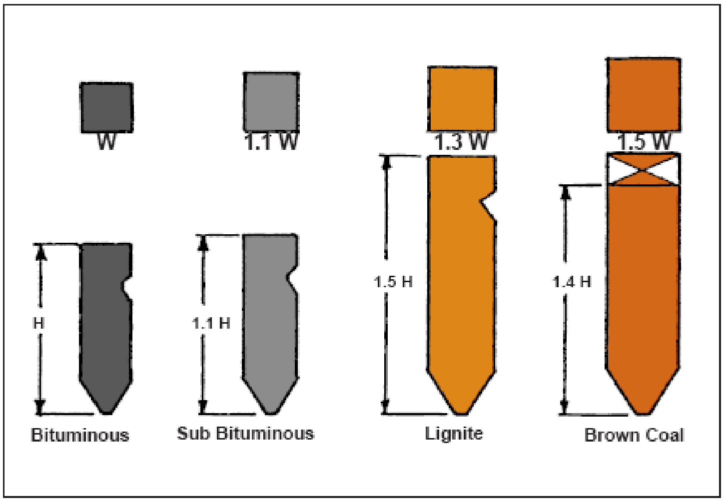
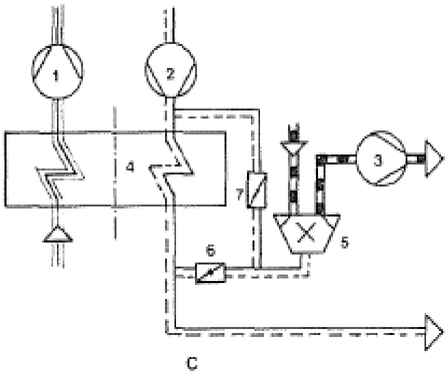


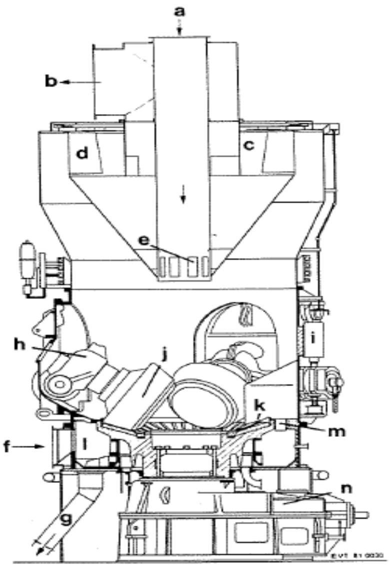
Figure 5.2 Comparative dimension of coal firing

For higher moisture coal, hot flue gas may be utilized for coal drying instead of hot air.

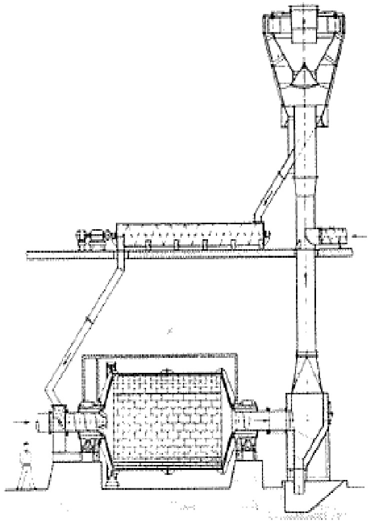


1.ID fan
2. Primary air fan
3. Mill fan (optional)
4. Air heater
5 .Mill
6. Hot air
7. Cold air (tempering air)

Figure 5.3 Mill schematic: Hot and cold air for drying



Vertical spindle mill



Horizontal tube mill

Figure 5-4 Conventional PC firing

PC firing system for lignite

Lignites are characterized by high moisture content which may be as high as 70%. Because of this, lignites need to be dried with a high temperature drying medium before being ignited to ensure a good ignition and burnout behaviour in a pulverized coal fired unit. The drying is concurently combined with the grinding process in a special mill called wheel mill or beater mill illustrated in **Figure 5.5**. Unlike hard coals such as bituminous coal or anthracite, hot flue gas is used as a drying medium instead of hot primary air.

Lignite is fed into the mill, where it is mixed with recirculated hot flue gas from the top of combustion chamber, having a temperature of appox. 1,000^{o}C. Hot and cold air are used to temper the mill. In the beater mill, the lignite are dried and ground, then the mixture of dry pulverised lignite, vapour, recirculated flue gas and air is directly injected into the furnace through PC burners.

The PC firing systems for lignite can be direct firing without or with vapour separation. Depending on the moisture content of the lignite and the requirements for stable coal firing at part loads, an arrangement with vapour separation before injecting the mixture into the furnace may be used.

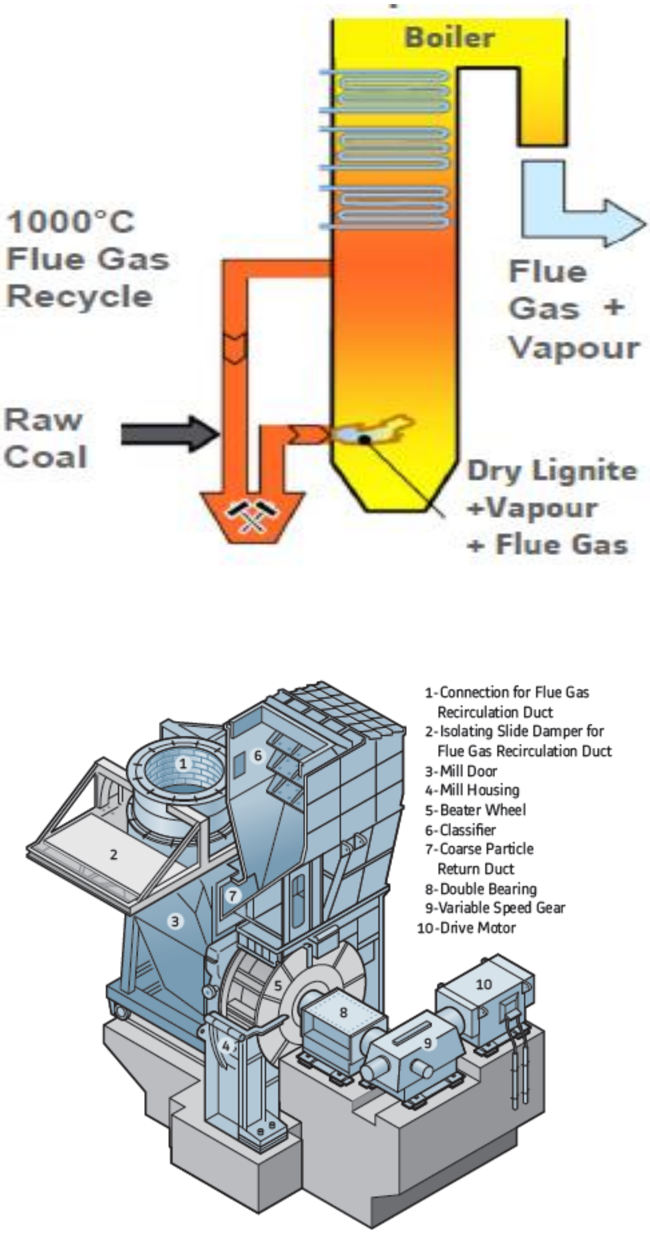


Figure 5-5: Typical PC firing for lignite (Source: Altom Power)

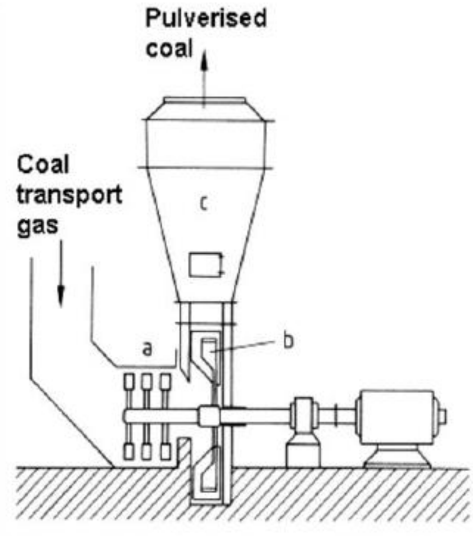


Figure 5-6 Beater Mill

Milling and firing system

The mills pulverize the lignite and dry the fuel with a moisture content of 48-60% using hot flue gas. Then combined with air heated by the flue-gas air heater, it is blown into the furnace of the steam generator and burnt. Combustion is constantly monitored so that the lignite and air mass flows are optimal for minimizing the production of nitrogen oxides (NO_X). The 200mg/Nm³ NO_X limit can be reliably achieved without the need for SCR. The lignite is burnt at temperatures of about 1,200°C. The hot flue gas that emerges during combustion flows upwards through the steam generator transferring heat to the outer walls formed by tubes and to the tube banks suspended in the flue-gas flow. Heated feedwater flows through these tubes and is evaporated and superheated. Beyond the top-most bank of heating surfaces, the flue gas is directed downwards through the open-pass ducts across the two flue-gas air heaters. After flowing through these heat exchangers, the flue gases, cooled to approx. 160°C, are ducted in two parallel lines to the flue gas cleaning system (dust collection and desulphurisation).

Firing with pre dried lignite

Power plant development is increasingly determined equally by the importance of efficiency increase and emission reduction, and economic efficiency based on the lowest possible investment and operating costs and high availability. This requires innovation development as in the case of lignite pre-drying.

Pre-Drying

Lignite pre-drying has been developed by RWE Rheinbraun to a level that enables significant further improvements in the lignite-based power plant process efficiency cost effectively.

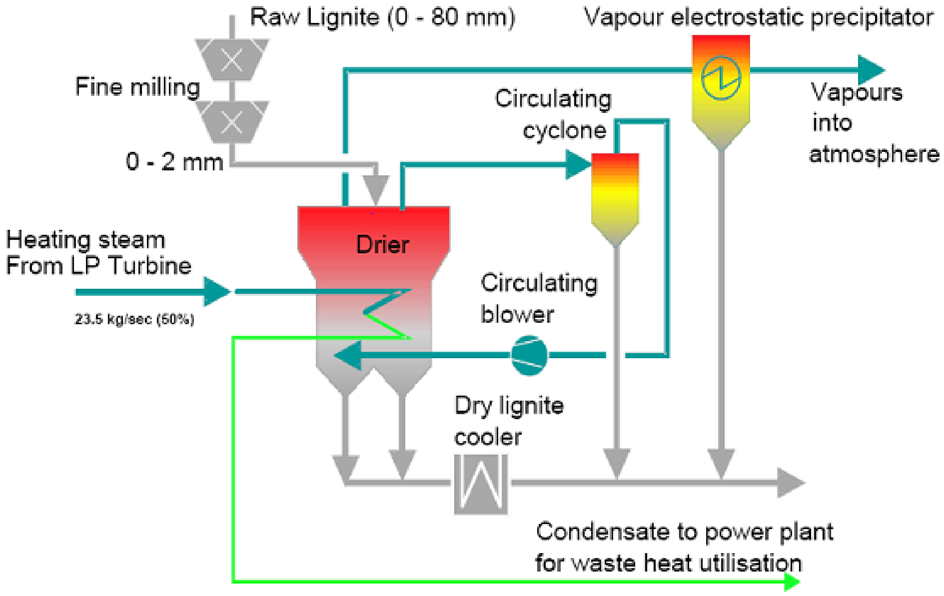


Figure 5-7 Coal Drying - the Key to Efficiency Increase

The process of integrated milling and drying used in the large pulverized lignite-fired power plant units is not the best solution thermodynamically but has been the most economic. Separate drying systems using low-temperature heat had been uneconomic so RWE RHEINBRAUN decided to develop a new drying process, the so-called 'Wirbelschicht-Trocknung mit interner Abwärmenutzung' (WTA which stands for fluidized-bed drying with internal waste heat utilization) technology.

Raw Coal Feeders

Gravimetric type raw coal feeders with microprocessor based precision weighing and calibration devices, one for each mill. The feeders shall be complete with motor, coupling, coupling guards, base plate, foundation bolts, sliding joints, paddle type switches to detect presence or absence of coal on feeder or choking of feeder, speed variator, speed sensors, coal motion monitors, and strain gauge type weight measuring system with all instrumentation.

Coal Pulverisers

The coal pulverisers shall be vertical spindle type medium speed mills (like pressurized type bowl mills, ball and race mills such as MBF/MPS/MRS mills etc. or the approved equivalent). The coal pulverisers shall conform to sizing/ standby requirements stipulated elsewhere in the specification. Coal pulveriser type will use hot air as carried fuel media to the burner. This shall be suitable for dried coal outlet from external coal dryer.

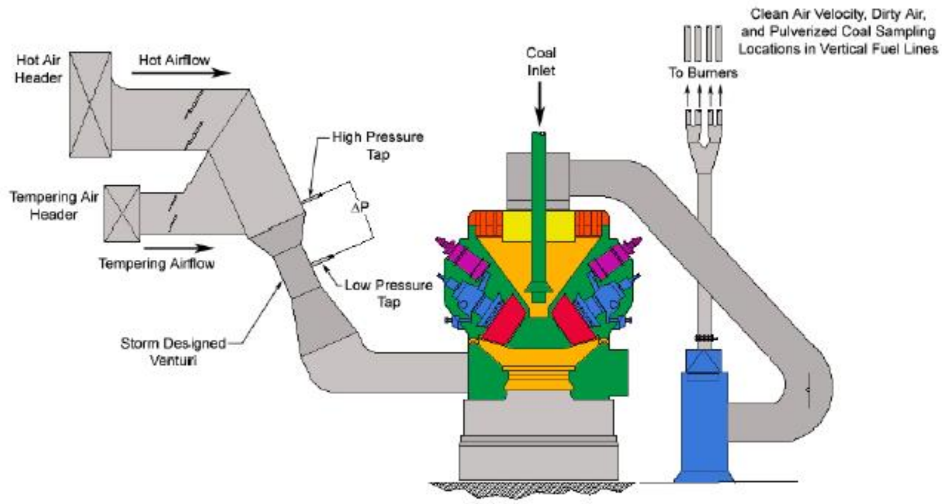


Figure.5.8 Typical Coal pulveriser for PC Boiler

Table 5-2 Effect of Coal Rank on Furnace Size

Allowable Pulverizer Outlet Temperatures[89]

	Storage		Direct		Semidirect	
	F°	C°	F°	C°	°F	C°
High –rank, high-volatile bituminous	130*	54*	170	77	170	77
Low-rank, high-volatile bituminous	130*	54	160	71	160	71
High-rank, low-volatile bituminous	135*	57*	180	82	180	82
Lignite	110	43	110–140	43–60	120–140	49–60
Anthracite	200	93	?	?	?	?
Petroleum coke (delayed)	135	57	180–200	82–93	180–200	82-93
Petroleum coke (fluid)	200	93	200	93	200	93

Summary for PC Boiler

- The conventional PC for lignite boiler utilised exhaust gas to heat up the coal in milling process. This is related to high volatile and high moisture coal.

With this configuration, it is needed for the boiler size to be bigger than the normal sub bituminous coal. The impact is high investment cost and low boiler efficiency.

- Using coal dryer, a standard PC boiler with hot air coal mill can be adopted. The benefit will be both in higher boiler efficiency and lower boiler investment cost due to smaller boiler dimension.

5.2 Fluidized Bed Combustion

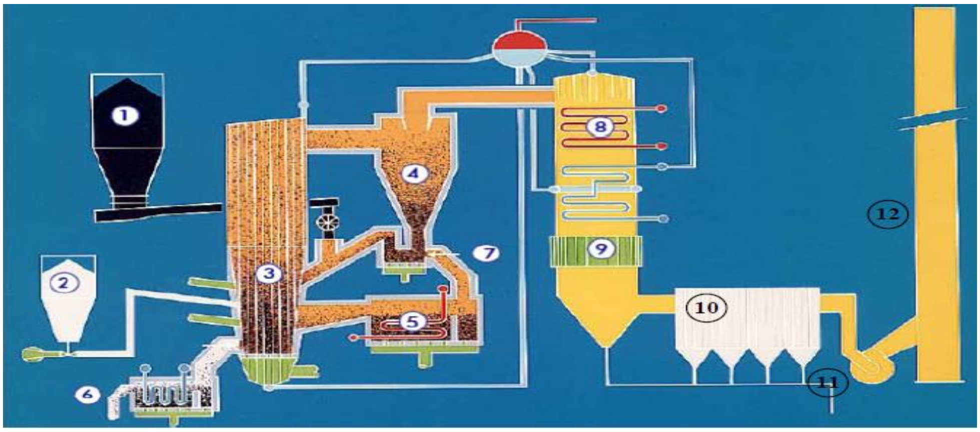
The fluidized bed technology emerged as early as in the early 1920's, however, due attention to its applicability in power generation was not paid until the 1970's when environment-friendly alternatives for solid fuels were sought. Since then a lot of advances have been made which makes the CFB firing technology become competitive with the PC combustion technology. The fluidized bed technology enables some unique features, such as multi-fuel capability, biomass co-burning, and attractive emission performance. Many fluidized bed boilers burn fuels that can otherwise not be utilized at all considering performance, operability, and emissions considerations. CFB boilers can burn high moisture fuels, such as different types of sludge and biomass, high ash waste coals (anthracite culm and bituminous gob), and low and extremely low reactivity fuels (anthracite and petcoke). Further, certain waste products can be used e.g. tire derived fuels (TDF) and refuse derived fuel (RDF). Oil refining byproduct, petroleum coke (petcoke), is widely used in CFB boilers, because it is often the most economic fuel.

In the 1970s both Ahlstrom and Lurgi developed CFB boiler technology for solid fuel combustion. The first commercial unit was started up in Pihlava, Finland, in 1979. The first boilers were small, but enabled the manufacturers to gain experience and gradually scale-up the technology to 300 MW sizes, where the technology is today with two units of this size operating in the US (Jacksonville Electric Authority in Florida), one unit of this size in Italy (Sulcis) and more than 30 units of this size in China. In 2009, Foster Wheeler put in commercial operation the world's first supercritical CFB boiler, 460 MWe capacity, in Lagisza, Poland. More supercritical CFB boilers are under construction, including 4x550MW units in Samcheok (Korea) and 330MW Nocherkasskaya in Russia.

Table 5-3 References of large capacity CFBs

Place	Capacity	Operation	
Provence, France	1x300MWe	1996	
Guyama, Puerto Rico	2x300MWe	2003	
Seward, US	2x260MWe	2004	
Sulcis, Italy	1x340MWe	2004	
Baima, China	1x300MWe	2006	
Kaiyuan, China	1x300MWe	2006	Lignite
Turow, Poland	3x262MWe	1995	Lignite
JEA, the US	1x300MWe	1995	
Lagisza, Poland	1x460MWe	2009	
Mao Khe, Vietnam	2x220MWe	2013	

The CFB boiler operates between two extremes: the fixed bed mode as in stokers (grate-fired boilers) and the entrained mode, i.e, the solids are transported with gas, as in PC boilers. Coal and crushed limestone are fed into the lower portion of the furnace. The majority of the solids are entrained by the combustion gases to the upper furnace and then to cyclones which separate them from entraining gas for recycling back to the furnace bed, part of the entrained solids will form clusters and return back to the furnace bed, and part of the solids remain in the bed. Most of the gas that entrains the solids enters the furnace (combustor) through fluidizing nozzles located in the fluidizing grate that forms the floor of the combustor. The combustion occurs at a temperature of 850°C to 930°C depending on the fuel specification. Thanks to the relatively low combustion temperature which does not favor NOx formation, and in-furnace desulfurization capability, the NOx and SOx emissions are lower to an extent that post-combustion treatment (SCR or SNCR for NOx, FGD for SO2) might not be required.



1. Fuel Silo
2. Limestone Silo
3. Furnace
4. Cyclone
5. Heat Exchanger (optional)
6. Ash Cooler
7. J-Valve
8. Heat Exchange Surfaces
9. Air Preheater
10. De-duster
11. ID Fan
12. Chimney

Figure 5-9 CFB Boiler

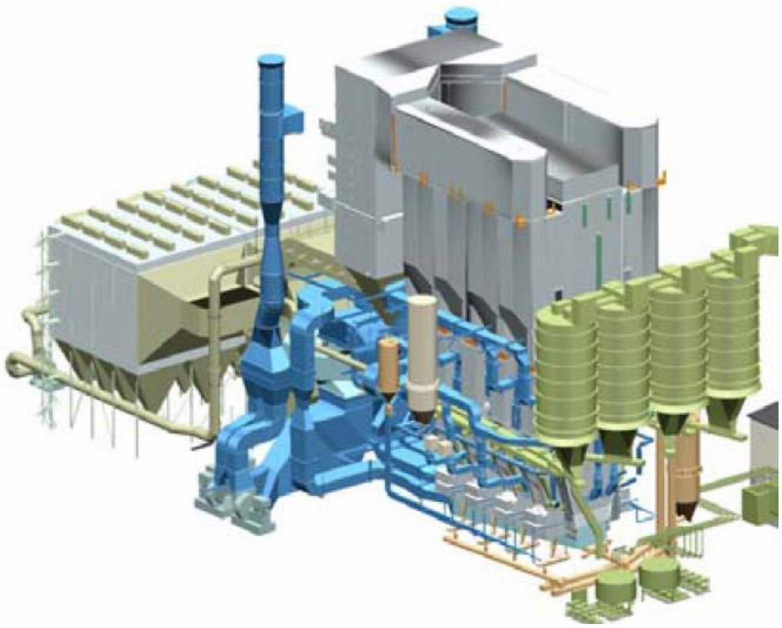


Figure 5-10 Lagisza 460 MW supercritical CFB

Atmospheric Fluidised Bed Combustion

It is generally accepted that for optimum efficiency, fluidised bed combustors (FBC) need to be designed for a specific coal type. The FBCs are suited to lower grade fuels but at a reduced thermal efficiency. The fuel issues depend on the fluidised bed combustor type. e.g. bubbling beds, CFBC and PFBC.

It is reported that the LHV and moisture content of the fuel has a major impact on heat release in a CFBC. For instance lignite coal with 57% moisture and LHV of 4.38 MJ/kg suggests 35% of heat would be removed in the circulating loop and 65% in backpass.

For the hard coals, the values are reversed: 65% circulating loop, 35% back pass. The coal with 37% moisture and 7.89 MJ/kg would give about 50% in each. In addition, the high flue gas flow for the lignites, compared to the hard coals, will reduce the boiler efficiency in a similar way to the supercritical boilers. Therefore, the thermal efficiency of fluid bed combustion generally decreases with increasing fuel moisture, volatile matter and ash content and with decreasing LHV. In the worst case the high moisture and ash contents may depress the bed temperature to an extent where burn-out is affected adversely.

The amount of limestone that needs to be added to the CFBC to reduced SO_2 depends on the coal LHV, sulphur content, calcium species in the ash and the target emission level.

The NOx emissions from CFBC boilers have been found to vary with coal type and increase with increasing: coal heat content, limestone addition and excess air. Most of the NOx produced is NO but the low temperature of CFBC boilers also results in the formation of N2O (nitrous oxide). The N2O is a strong greenhouse gas and is believed to cause ozone depletion. The trend for N2O emissions with coal type is less than for hard coals clear because emissions increase then decrease with bed temperature. The Greek lignites would give low bed temperatures (under 800°C) and therefore both low NO and N2O although a minimum temperature for satisfactory combustion must be achieved. CFBC boilers are likely to require additional NOx removal to achieve the required emission limits.

Experiences of CFBC power plant uis as below.

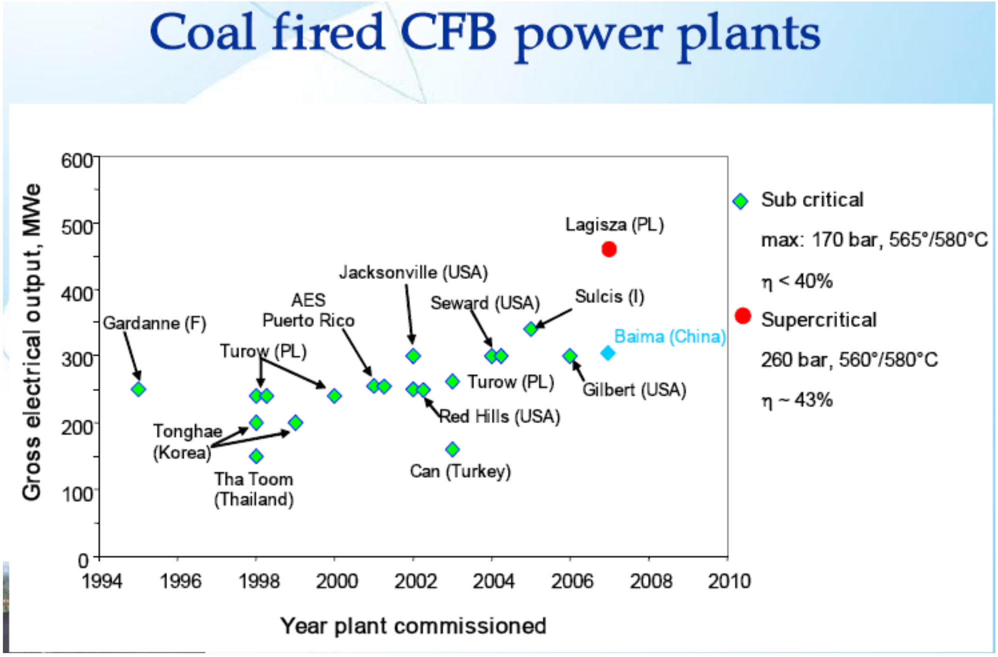


Figure 5-11 Coal Fired CFB Power Plants

It has been shown that practically 300 MW CFBC plants are only in USA. In Indonesia there only one site in PLTU 2x100 MW Tarahan with the Alstom boiler.

Operation in Tarahan power station showed that technically CFBC can be operated in a normal comndition, however there was reported that abrassion on furnace wall is happened faster than they designed. This could be caused by Indonesian coal that has very low ash content so that addition of bed material of silicone sand is high. This could lead to high abbrasive potential. It is also reported that during 2008 it has been shut down three times with each inspection duration of 3 weeks each shutdown to replace the worn wall tube.

List of installed CFBC Foster Wheeler below is China product, there is no 300 MW plant installed yet.

Table 5-4 List of CFBC Power Plant

YEAR OF COMMISSION	CUSTOMER	NO. OF UNITS	CAP. MWe	FLOW K lb/hr (Kg/s)	PRESS. psig (bar)	TEMP. F (°C)	SUPPLIER	FUELS
2001	Shijiazhuang Power Plant	4	100				DFBW	Coal
2001	Baodin Power Plant	2	110				DFBW	Coal
2001	Sinopec Jingling Petro-Chemical Co. Jingling	2	50	485 (61.1)	1420 (98)	1005 (540)	FWEO	Coal, Petroleum Coke
2000	Yibin Power Plant Sichuan	1	100				DFBW	
2000	Taiwan Cogeneration Corp (TCC) Tainan Hsien, Taiwan	1	45	440 (55.5)	1847 (127.4)	1005 (541)	FWEO	Bituminous Coal, Sub-Bituminous Coal, Tires, Sludge
1999	Asia Pulp & Paper	2	100	880 (110)	1815 (125)	1000 (537)	FWEO	Coal
1999	Asia Pulp & Paper	1	57	550 (69)	1825 (125)	1000 (537)	FWEO	Coal
1999	Zhenhai Refinery Ningbo	2	50	485 (61)	1477 (98.1)	1005 (540)	FWEC	Petroleum Coke
1998	Zaozhuang Coal Mine Bureau Shangdong	1	6	77 (9.7)	551 (38)	842 (450)	FWKK	Coal Washery Sludge 100%
1998	Dalian Xianhai Thermal Power Corp. Dalian	2	50	485 (61)	1477 (98.1)	1005 (540)	FWEC	Bituminous Coal
1998	Sichuan Fuling Aixi Power Generating Co., Ltd. Sichuan	1	50	485 (61.1)	1436 (99)	1004 (540)	FWEC	Coal
1998	Ban Yu Paper Mill Co., Ltd., Peikang, Taiwan	1	50	441 (55.6)	1842 (127)	1005 (541)	FWKK	Bituminous Coal 100% Semi-anthractie Coal 100% Paper Sludge 10%
1996/ 1997	Ningbo Pulp & Paper Mill Ltd. Zhejiang	2	50	485 (61)	1420 (98)	1004 (540)	DFBW	Sub-Bituminous Coal, Paper Mill Sludge
1996	Hangzhou Thermoelectric Plant, Hangzhou	1	50	485 (61)	1436 (99)	1005 (540)	FWEC	Coal
1996	CMIEC/Neijiang Neijiang	1	100	905 (114)	1421 (98)	1004 (540)	FWEO	Coal – Anthracite
1995	Dalian Industrial Chemical Co., Dalian	2	50	484 (60.1)	1450 (98)	1005 (540)	FWEC	Coal
1995	Panjin Liaohe Thermal Power Co., Panjin	1	55	485 (61.1)	1798 (124)	1004 (540)	FWEC	Coal
1988	Yuen Foong Yu Paper, Taipei, Taiwan	1	30	287 (36.1)	1886 (130)	986 (538)	FWEO	Petroleum Coke 100% Bitumnous Coal 100%

Summary for CFBC Boiler

- CFBC technology is technically suitable for coal that has high TM.
- CFBC technologies are still relatively unproven and the demonstration plants vary significantly in design. Lack of experience for CFBC plant of 300 MW unit.
- The questionable factors for CFBC Boiler is related to the material durability of wall tube arround furnace, so that the availability is still reported low (<76%).

5.3.Critical factors in the choice of a technology

- High efficiency means: (+1%point)
  - Less fuel consumption. (2.5%)
  - Less emissions (also CO_2)(2.5%)
  - Lower electricity prices. (2%)
- Emissions compliant with regulations or better.
- Best available technique.
- Proven technology / Experience.

PC firing vs CFB firing

Table 5- 5 below shows the comparison between the CFB boiler and PC boiler as a candidate for the plant burning the specified lignite.

Table 5-3 Comparison between CFB boiler and PC boiler

Considered Factors	PC Firing	CFB Firing	Application to Project
Technology Proven	Yes	No for supercritical units	Proven technology is required
Availability of large units	Yes	No	Largest unit in operation is 460MWe capacity, and it is one and only.
Fuel Flexibility	No	Yes	Not important for the project, since only lignite from the nearly mine will be burnt.
NOx Emission	< 200 mg/Nm^3 can be achieved with in-furnace NO_x suppression measures	Same	Both technologies can meet the NO_x emission limits stipulated by authorities or suggested in IFC guidelines without additional equipment (SCR or SNCR)
SO_2 Emission	Scrubber required to control SO_2 to meet the regulatory limits	Limestone addition to furnace required to control SO2. No post-combustion treatment (scrubber) is required	Both technologies can meet the SO_2 requirement
CO Emission	~ 125 mg/Nm^3	~ 250 mg/Nm^3	Both technologies can easily meet the CO emission limits
Boiler Efficiency	High, unburnt carbon loss < 5%	Slightly lower than PC, unburnt	Applicable as it impacts plant efficiency

Considered Factors	PC Firing	CFB Firing	Application to Project
		carbon loss: ~ 1.0 %	
Boiler Reliability	Good	Data not available for supercritical units. Less reliable than PCs for subcritical units	Important for project
O&M Cost	Base	Similar*	Important for project
Capital Cost for Boiler Proper including refractory	Base	35-40% more**	Important for project
Plant Capital Cost	Base	~3-4% more***	Important for project
*CFB has lower reliability and more tube surface erosion and refractory maintenance, however, excludes the O&M cost for external FGD. **Based on input from Dongfang Boiler Corp on 300 MW subcritical units. ***Based on input from Dongfang Boiler Corp on 300 MW subcritical units.			

As can be seen from the above, the specified lignite is suitable for both CFB and PC combustion. Both technologies can meet the NO_x requirement without using de-NO_x equipment (SCR or SNCR) for the specified lignite. CFBs use of limestone injection to the furnace for SO2 capture will require less equipment than PCs using wet limestone scrubber for SO2 capture.

The major obstacle to utilize CFB technology for this project is the limited references and availability of large supercritical boilers. If CFB technology is to be selected, a two plus one configuration (two subcritical boilers feeding one steam turbine) has to be used for a 600MW unit. This will require more footprint and result in lower eficiency, higher investment and higher maintenance costs.

6 LIGNITE COAL FIRED POWER PLANT TECHNOLOGY

6.1 Steam cycle parameters

The boiler technology options available for large, pulverized coal-fired power plants are subcritical, supercritical and ultra-supercritical, while subcritical and supercritical options are available for large CFB boilers. Subcritical power plants operate at steam pressure of less than 190 bar, where the steam is a mixture of liquid and gas, and drum-type boilers are generally used.

The steam at 221 bar and 374.15°C is said to be in a critical state. At a critical point, the density of water and steam are the same. Further latent heat at this point is zero, which means there is no steam–water mixed phase and boilers operating above critical parameters do not have a boiler drum that separates steam from water. Supercritical plants and ultra-supercritical plants operate at steam pressure of more than 221 bar and use once-through boilers.

The following table gives an overview of the design parameters (ranges for sub-, super- and ultra supercritical designs).

Table Error! No text of specified style in document.**-1 Typical steam cycles**

Parameter	**Temperature [°C]**	**Pressure [MPa**
Subcritical	<540	15÷17
Supercritical	<580	24÷26
Ultra supercritical	580 - 630	26÷31

The higher the steam parameters are, the higher the efficiency of the water-steam cycle and the lower the fuel consumption. Reduction of fuel consumption will reduce the plant operating cost and the amount of gas emissions. With the steam parameters of 24÷25Mpa and 565°C/565°C superheat/ reheat, a 600MW class unit will have approximately 3% heat rate improvement over a typical subcritical unit (17.6MPa, 540/540^{o}C) of this size; of the 3% improvement, about 1.5% comes from the increase in the pressure and 1.5% from the increase in the steam temperature. The following figure shows the plant heat rate improvement as steam pressure and temperature get higher.

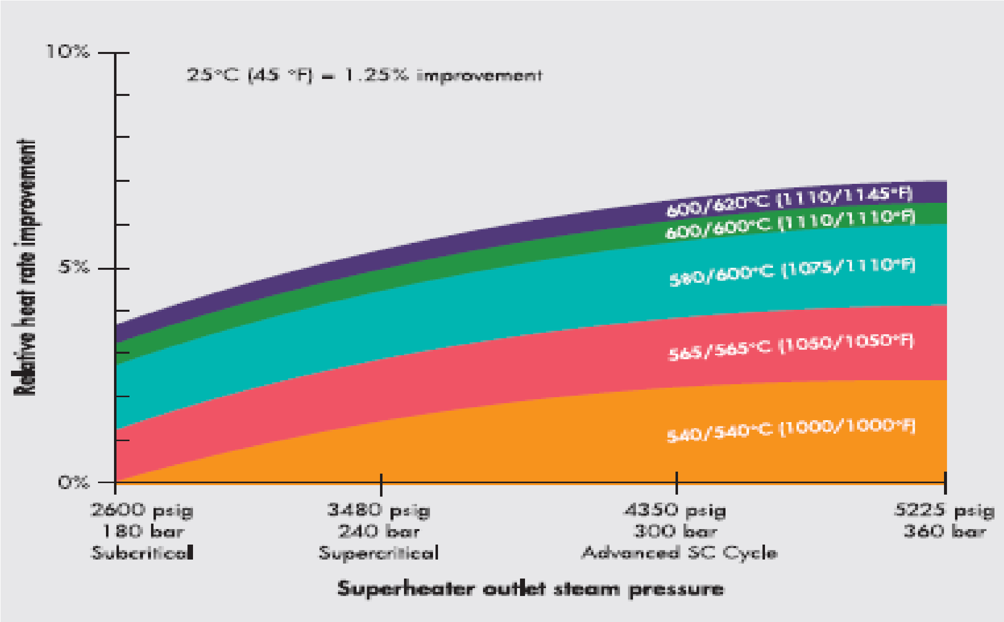


Figure Error! No text of specified style in document.**-1 Heat rate improvement vs. steam parameters (from Alstom)**

On the other hand, high steam temperature will result in higher investment expenses of the turbine and the boiler because more expensive pressure part materials are used. As illustrated in **Figure 6-2**, P91 can be used for temperatures up to 580°C, P92 for temperatures up to 620°C, but for temperatures above austenitic (high nickel, high chrome) materials must be applied. All supercritical and ultra-supercritical plants use once-through boilers whose more complex construction also contributes to higher investment costs. In general, units with large capacity and expensive fuel will tend to use high steam parameters. The tendency in power generation industry has been to use increasingly high steam temperature and pressure (**Figure 6.3**), thanks to the availability at reduced cost of advanced materials.

The supercritical technology has become a standard solution in the power industry in developed economies for large coal-fired power plants due to a higher efficiency than subcritical technology. The supercritical technology offers equivalent reliability and availability, while the lifecycle costs of supercritical plants tend to be lower than those of subcritical plants. A supercritical plant costs about 2% more than a subcritical plant to supply and install, while fuel costs are considerably lower due to the increased efficiency and operating costs. Supercritical plants have lower emissions than subcritical plants per unit of electricity generated. A 1% increase in efficiency reduces the specific emissions of nitrogen oxides, sulphur dioxide, particulates and carbon dioxide by 2.5% – 3.0%.

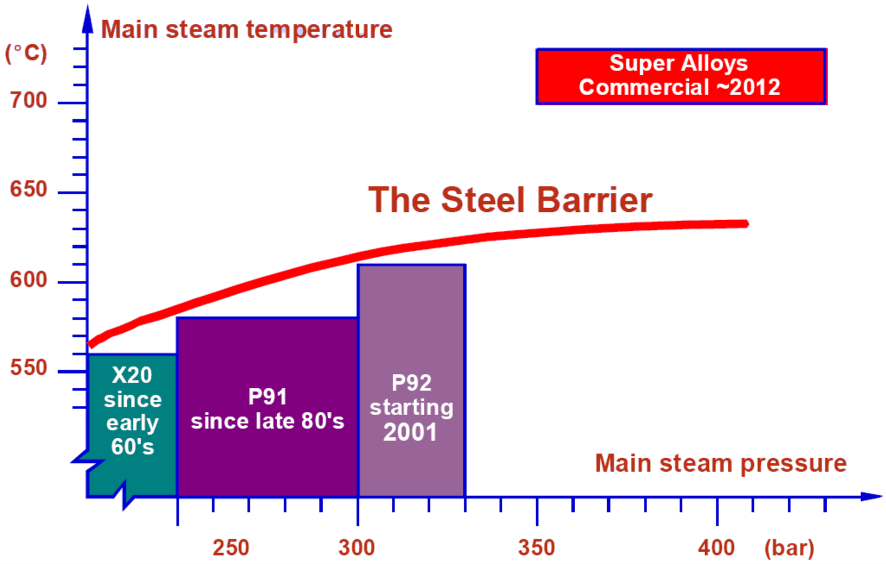


Figure Error! No text of specified style in document.**-2 Maximum steam temperature vs materials**

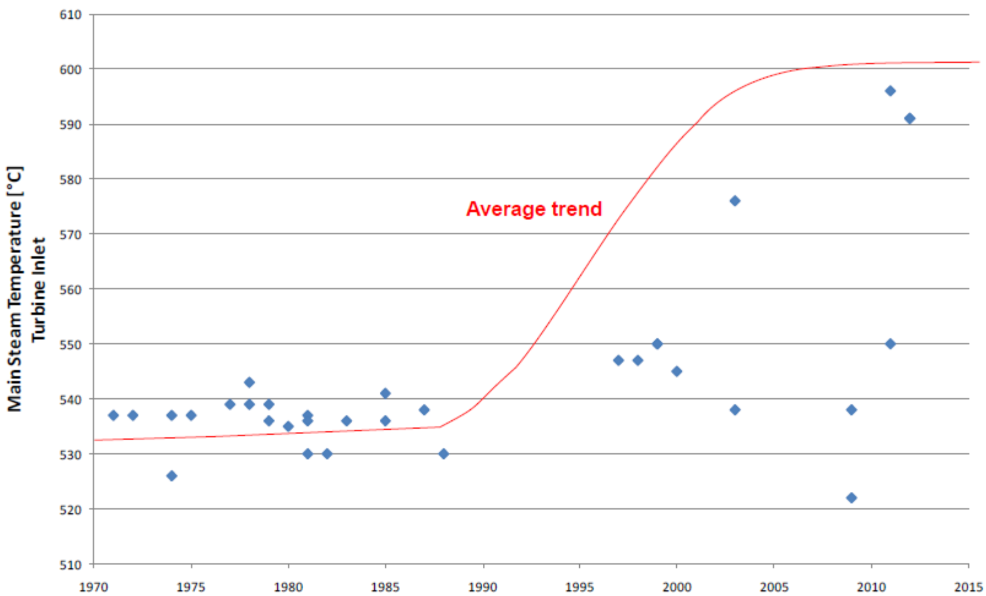


Figure Error! No text of specified style in document.**-3: Development of main steam temperature**

In the past few years, supercritical units have also become the standard selection for large fossil power plants in Asia. China meanwhile has over 300 units of 600 MW or larger capacity in operation since 2002. All critical components of these units, such as boilers, turbines, high alloy metals (tubes, pipes, and forgings), and feedwater pumps, are imported from the West or are based on transferred technology.
Currently, in the Chinese power plant equipment market, most 600-660 MW units are supercritical units with 24-25 MPa pressure and approx. 565°C temperature. 1,000 MW ultra-supercritical units are available with slightly higher steam parameters (26-27 MPa, and approx. 600°C). The main limiting factor for higher pressures and temperatures is the availability and leadtime in procuring the more advanced materials.
By 2013 close to 1,000 supercritical and ultra-supercritical power plants are in operation worldwide by 2013: about 170 units in the U.S., about 60 units in Western Europe, about 60 units in Japan, 280 units in Russia and Eastern Europe, and the rest in China.

6.2 Unit sizing and plant technology

For the planned large power plant, there are possible sizing options:

- 2x600MW units
- 3x400MW units
- 4x300MW units
- 8x150MW units

Below table illustrates the comparison between these options.

Table Error! No text of specified style in document.**-2: Comparison of unit sizes**

Comparison Criterion	**Option-1: 2x600MW**	**Option-2: 3x400MW**	**Option-3: 4x300MW**	**Option-4: 8x150MW**
Subcritical steam condition available	yes	yes	yes	yes
Supercritical steam condition available	yes	limited	no	No
PC boiler available	yes	yes	yes	Yes
CFB boiler available	no	limited	yes	Yes
Plant availability	base	similar	similar	Similar
Grid stability	base	better than 1	better than 2	better than 3
Land requirement	base	more than 1	more than 2	more than 3
Investment cost	base	more than 1	more than 2	more than 3
Plant efficiency	Base	less than 1	less than 2	less than 3
O&M cost	Base	more than 1	more than 2	more than 3

Market availability

High moisture lignite like that to be used for this project can only be burned most efficiently in a properly designed CFB boiler or a PC boiler especially designed to burn this fuel.

If PC technology is to be applied, it should be noted that only a few OEMs can design and supply the lignite firing system including Alstom, Babcock Hitachi and Steinmueller (IHI). Recently, Chinese Harbin also has established some capability in manufacture of high moisture lignite fired PC boilers.

Only a limited number of OEMs can supply CFB boilers of 300MW or larger size, including Alstom and Foster Wheeler. Major Chinese OEMs like Dongfang and Harbin are licensed by either Alstom or Foster Wheeler for large size CFB boilers. Some of them have developed their own "in-house" design of 300MW plus CFB boilers. It is said that some in-house design CFB boilers have been commissioned inside China, however, the feedback on the performance of these boilers is very limited. Below are boiler manufacturers with lignite experience:

Table Error! No text of specified style in document.**-3 Boiler manufacturers with lignite experience**

Maufacturer	Lignite Experience
Alstom	PC & CFB
Foster Wheeler	CFB
Dongfang Boiler	CFB
Harbin Boiler (HBC)	PC & CFB
Babcock Hitachi	PC
Deutsche Babcock	PC
Steinmüller (IHI)	PC
Austrian Energy & Environment (AE&E)	CFB
Mitsubishi Hitachi	PC
Rafako	PC & CFB

Plant availability

The availability of a 600MW unit is not much different compared to a smaller size unit, thus the overall availability of a plant consisting of larger units is almost similar to that of a plant consisting of smaller units.

However, a plant consisting of small size units tends to level the plant output over time: a trip, forced shutdown or planned outage of a single unit does not cause much decrease in the plant output, which is not the case with a plant consisting of larger size units. In this term, the “instantaneous” availability of a plant with smaller size units tends to be higher than that of a plant with larger size units.

Grid stability

A trip or load rejection of a smaller size unit will cause fewer disturbances to the grid than that of a larger size unit. In other word, a plant consisting of smaller size units is advantageous to a plant of the same size consisting of larger size units in regard to the grid stability requirements.

For a certain grid, the size of a new generating unit should not exceed a certain level to ensure the grid stability.. It is very likely that a 600MW unit, which is then about 5% of the total capacity of the grid, will not cause much disturbance to the grid in the event of trips or load rejections; however, this should be confirmed by a grid stability study.

Land requirement

At the same plant capacity, a plant consisting of larger units requires less footprint than a plant consisting of smaller units.

A 2x600MW coal-fired power plant normally requires 42 to 44 hectares of land to construct, while a 4x300MW coal-fired power plant may need as much as more than 50 hectares.

Investment

At the same plant capacity, a plant consisting of larger units is less capital extensive than a plant consisting of smaller units. The reasons include:

- Plant with smaller unit size requires more materials for manufacture/ fabrication of plant components
- Smaller units require more materials and labours to construct the plant (more civil/ structural/ installation work)

As a rule of thumb (according to Altom), the economy of scale can be expressed by an exponential formula, $IC1/IC2 = (S2/S1)^k$, where S2 and S2 are unit sizes in MW, IC1 and IC2 are investment costs for size 1 and size 2, and k normally is between 0.7 and 0.9.

Plant efficiency

A 150MW or 300MW unit normally is less efficient than a larger size unit, the reasons include:

- Smaller units normally are not designed for advanced steam condition.
- Smaller auxiliaries (pumps, fans, etc) are normally less efficient than larger ones.

At partial plant loads, the units of a plant consisting of small units can still be operating at its high to full load, which bring in better part load efficiency. Despite of this, the overall efficiency of a plant with smaller units is still lower.

O&M cost
A plant consisting of smaller units requires more manpower to operate and maintain. The above comparison illustrates that the 600MW PC unit size is the most favourable for a 1,200MW power plant. Fichtner prepared a comparison of electricity generation costs for 600MW unit size options with different steam conditons.

- 2x600MW subcritical units (17.6 MPa, 540/540^{o}C)
- 2x600MW supercritical units (24.7 MPa, 565/565^{o}C)
- 2x600MW ultra-supercritical units (26.0 MPa, 566/600^{o}C)

The following table compares the options. The comparison was based on following the assumptions:

- Amortization period : 25 years (plant life)
- Discount rate : 7.5%/year
- Plant load factor : 80%
- Coal price : US$35/ton

Table Error! No text of specified style in document.**-4: Comparison of electricity generation costs**

Item	**Unit**	**(a)**	**(b)**	**(c)**
Net Capacity	kW	1,200,000	1,200,000	1,200,000
Investment	Mil. US$	2,260,000	2,320,000	2,380,000
Amortization Period	Year	25	25	25
Discount Rate (R)	%	8	8	8
Plant Load Factor	%	80.0	80.0	80.0
O&M Cost Rate	%	2.500	2.500	2.500
Coal Price	US$/ton	35.00	35.00	35.00
Boiler Efficiency on LHV	%	87	87	87
Turbine Heat Rate	kcal/kWh	1,880	1,790	1,716
Delivered Energy	Bil. kWh/y	8.410	8.410	8.410
Coal Consumption	Mil. Ton/y	8.008	7.666	7.349
Capital Recovery Factor	-	0.09368	0.09368	0.09368
Amortization Expense	Mil. US$/y	228.65	234.72	240.79
Amortization Cost	**cent/kWh**	**2.719**	**2.791**	**2.863**
Annual O&M Cost	Mil. US$/y	56.50	58.00	59.50
O&M Cost	**cent/kWh**	**0.672**	**0.690**	**0.708**
Annual Fuel Cost	Mil. US$/y	280.29	268.32	257.22
Fuel Cost	**cent/kWh**	**3.333**	**3.191**	**3.059**
Power Generation Cost	**cent/kWh**	**6.724**	**6.671**	**6.630**

Difference	**cent/kWh**	**0.094**	**0.042**	**Base**

Based on the above considerations, 2x600MW units with PC boilers and ultra-supercritical steam parameters appear to be the most economical option. The difference between (a) and (b) and (c) is minor, however will be more pronounced when the fuel price increases, which is very likely to occur in a foreseen future. This, and the fact that various lending institutions like ADB and World Bank have ceased financing steam power projects using the subcritical technology due to greenhouse gas emission policies, suggest that the 2x600MW ultrasupercritical option with PC boilers appears to be the option of choice. It is recommended that this option be the base case for the further project development.

6.3 Potential OEMs (Original Equipment Manufacturers) for boilers

The best-known technologies which have been dominating the supercritical boiler market are the Benson technology owned by Siemens AG and the Sulzer technology owned by ABB (formerly Asea Brown Boveri). Both technologies were developed in 1920s.

Siemens does not manufacture boilers and only licenses the technology. Detailed design and manufacture is carried out by about 20 licensees and sub-licensees. The major manufacturers holding Benson licenses include Deutsche-Babcock (Germany), Steinmüller (Germany), Austrian E&E (Austria), Ansaldo (Italy), Burmeister & Wain Energy A/S (BWE, Denmark), Doosan Babcock Energy (UK), Stork (Netherlands), Babcock-Hitachi KK (Japan), IHI (Japan, until 1995), Hyundai (Korea), Babcock & Wilcox (USA), Foster Wheeler (USA), and Dongfang Boiler Corp. (China). The Benson license is the market leader. ABB now holds the Sulzer license. Licensees include Alstom, Korean Heavy Industries (Korea), Formosa Heavy Industries (Taiwan), Mitsubishi Heavy Industries (MHI, Japan), Rafako (Poland), and Shanghai Boiler Works (China).

In 2002 the three (3) big Chinese boiler manufacturers (see table 6.3 below) bought the supercritical technology from the West and Japan, and started manufacture of large supercritical units. Their boiler technology sources are summarized below:

Table Error! No text of specified style in document.**-5: China's major boiler manufacturers and their source of supercritical technology**

	Supercritical Licensee (600 MW Class)	**Ultra-Supercritical Licensee (1000 MW Class)**
Shanghai Boiler Works, Ltd.	Alstom – CE, U.S.	Alstom Power Generation AG, Germany
Dongfang Boiler Corp.	Babcock Hitachi	Babcock Hitachi
Harbin Boiler Corp.	Doosan Babcock Energy	Mitsubishi Heavy Industry

Since then, hundreds of 60 x 600/660 MW supercritical units and dozens of 1,000 MW ultra-supercritical units have gone into commercial operation. Other dozens of 1,000 MW ultra-supercritical units and hundreds of 600/660 MW supercritical units are under construction or have been ordered so far. Babcock & Wilcox Beijing Company – a China-based joint venture between Babcock & Wilcox and Beijing Boiler Works – also has considerable capability in supplying large capacity supercritical boilers.

It should be noted that while various OEMs can supply supercritical boilers fired with bituminous and subbituminous coals, the number of those who can supply high moisture lignite fired boilers is not as many. It is the limited availability of lignite in most parts of the world that confines the market for these special boilers. While bituminous and subbituminous coals can be fired with a conventional firing system (i.e, those systems with vertical spindle mills where hot air from air heaters is used for drying coal and transport of pulverized coal to the furnace), high moisture (more than 30%) lignite can only be fired with a special firing system where very hot flue gas recirculated from the top of the boiler is used to dry coal in beater mills and transport pulverized coal to the furnace). Companies like German Babcock, Alstom (EVT) and Steinmueller developed and designed these systems. Nowadays Alstom and Babcock Hitachi are the companies capable of supplying these combustion technolo-gies for extreme wet lignite. This should be taken into consideration for the procurement planning.

6.4 Coal pre-drying

Coal Pre-drying describes the process of reducing the moisture content of a solid fuel before it is ground and further dried in milling equipment. In conventional lignite stations, the fuel is dried using hot flue gases, which are drawn off the steam generator furnace at a temperature of 900°C to 1,000°C and injected into the beater wheel mills: there evaporation of the lignite's moisture takes place while the coal is being pulverized. If this combined process is decoupled and separated into drying and milling, the lignite can be dried at a low temperature with greater energy efficiency. This significantly increases the efficiency of the power plant process as a whole. The plant efficiency is increased because of two factors:

- drying with a low temperature energy source in lieu of combustion energy means enery is more exergetically efficiently used
- the separation of vapour from pulverized coal results in a lower volume of exhaust flue gas, and allows the exhaust flue gas temperature to be lowered without concern of vapour condensation, both of which contributes to a reduced boiler’s exhaust loss. The separation of vapour from the pulverized coal blown into the furnace also contributes to flame stability. It is estimated that the plant efficiency improvement can be as high as 5 percentage points on a LHV basis when lignite is pre-dried from 50% to 12% moisture.

Various technologies have been developed for pre-drying low-rank high moisture coal, of which the most noticeable ones are the WTA technology (WTA technology is the German abbreviation for *Wirbelschicht-Trocknung mit interner Abwarmenutzung* developed by RWE (Rheinisch Westfaelische Energieversorgung), the other is DryFining™ developed by Great River Energy (United States). The similarity of these technologies is the utilization of a fluidized bed type dryer using a low-temperature energy source, as opposed to a high-temperature energy source in the system with hot flue gas recirculation.
The status-quo WTA technology is a fine-grain drying process and has been introduced with several variants, one of which is illustrated in Figure 6-4. The features of the WTA technology include:

- Supplying the drying energy via heat exchangers installed in the driers
- The source of drying energy to the driers being either low parameter steam (from turbine extraction, for example) or compressed vapour.
- Utilizing the latent heat of vapour evaporation for coal, or condensate pre-heating in the power plant
- Feeding the raw coal to driers at a particle size of less than 0.08 inch (<2 mm)

The WTA has found its applicability in several power plants using lignite-fired boilers in Germany. Four pilot and demonstration systems have been put in operation since 1999, 2002, 2003 and 2008 with a drying capacity (as raw lignite) of 53t/hr, 170t/hr, 27t/h, and 210t/hr respectively. The drying capacity of the biggest one is 210t/h of raw lignite, or 25% of the total fuel flow consumed by the host power plant of 1,100MW capacity. Another system, 140t/h drying capacity, has been planned for a lignite-fired power plant in Australia.

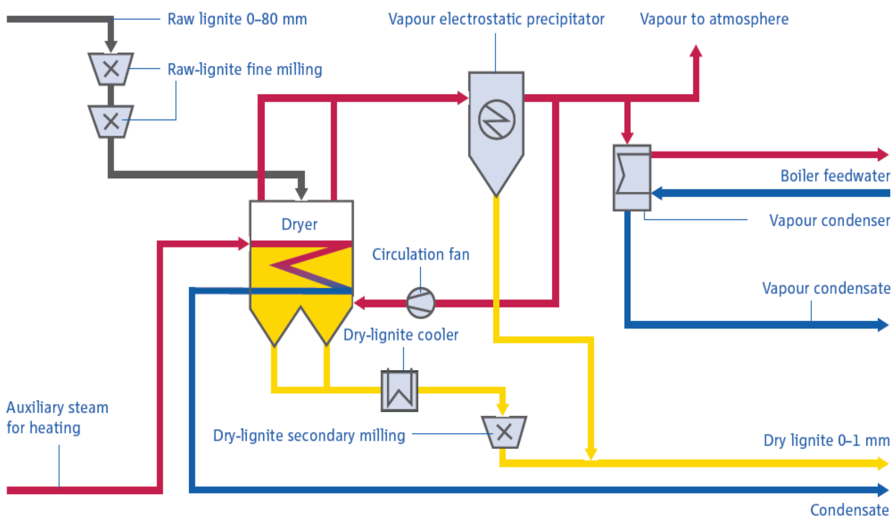


Figure **Error! No text of specified style in document.**-4 A variant of WTA technology (Source: RWE)

The DryFining^{TM}, developed by GRE (Great River Energy), was used at the full scale in 2009 at 1,200MW lignite fired Coal Creek Power Station in the United States, under the program ”Clean Coal Power Initiative“ sponsored by US Department of Energy. Besides, a feasibility study is ongoing on its applicability in a coal-fired power plant in Australia. The Coal Creek Power Station, however, so far has been the only example of the realization of the technology at an industrial scale, and the feedback from this power plant on the performance of the drying technology and equiment is limited.

The basic difference of DryFining^{TM} from WTA is that waste heat from exhaust flue gas after the air heaters is used to heat up water which is then used to heat up coal in coal dryers. In order to do so, gas/water heat exchangers are provided to extract waste heat from the exhaust flue gas. Part of drying heat is recovered from hot cooling water coming out from the condenser.

The DryFining^{TM} in Coal Creek Station reduces lignite moisture from around 39% to around 29%. The improvement in the plant efficiency is attributable to the decrease in the moisture content of the as-fired lignite, the heat recovered from exhaust flue gas, and the heat recovered from hot cooling water.

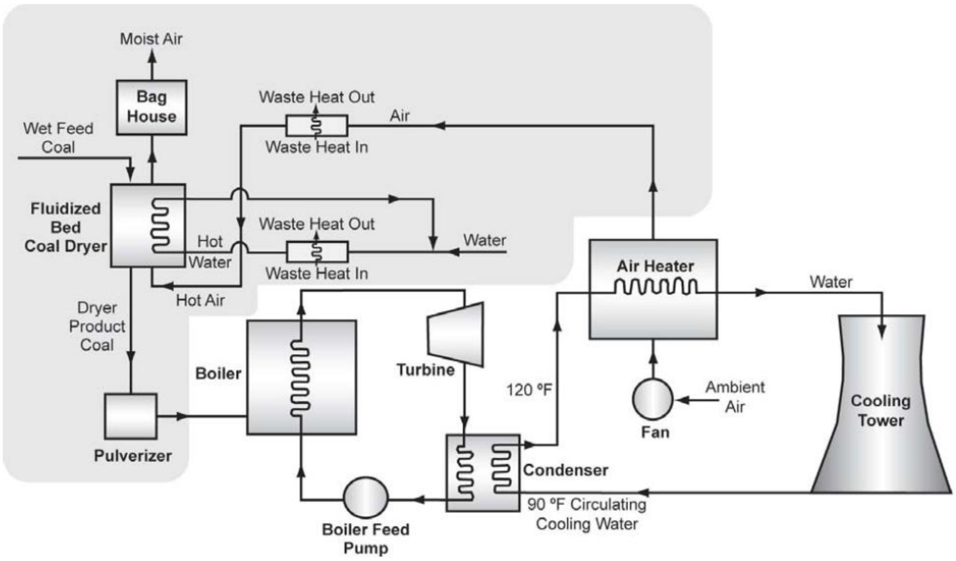


Figure **Error! No text of specified style in document.**-5 DryFining^{TM} schematic (Source: GRE)

Despite being seemingly promising, it is hard to assume that both the technologies have been fully commercialized: The DryFining^{TM} system at Coal Creek is still one of a kind, while WTA has not had any reference of full scale installations. The application of either of these techlologies poses technological risks. Furthermore, the integration of these technologies into power plants is still very costly, which is in the order of 70 Euros/kW as reported by RWE for WTA.

6.5 Boiler and Flue Gas Cleaning Technology

Lignite is fed into the beater mills (**Figure 6-6**) along with hot flue gas at a temperature of about 1,000ºC recirculated from the top of the furnace. The hot flue gas dries the lignite and and conveys the fine powders directly to the burners. Hot air from the air heater and cold air are also used to temper the hot flue gas. It is essential that as much moisture as possible be removed from the lignite, so that it can flow freely and does not become sticky (otherwize plugging may occur). Removing moisture is also important for quick ignition of the pulverized lignite, which helps stabilize the combustion process and improve carbon burnout.
The lignite is pulverized to an extent that the pulverized powders are less than typically 90 µm size (approximately 60 % through a 70 mesh screen). The hot flue gas heat reduces the lignite moisture content down to 10 to 20 %, i.e. to the required level for optimum combustion conditions. The finer the powders, the more favourable the combustion process, and the higher the combustion efficiency is, however, excessive grinding causes a waste of grinding energy. On the other hand, too coarse a powder does not burn completely in the furnace and results in higher unburnt losses.
From the mills, the mixture of pulverized lignite, moisture and transporting flue gas is directly blown into the furnace through a series of low-NOx burners arranged circumferentially around the furnace walls at various elevations (Figure 6-6). Hot air is added as combustion air. Combustion takes place at a temperatures of around 1200°C. Heat released from the combustion process is transfered to the water walls and heat absorption surfaces arranged in the gas path of the boiler.
The hot flue gas that emerges during combustion flows through the steam generator from bottom to top. In the process, it transfers heat to the outer walls, which consist of tubes, and to the tube banks suspended in the flue-gas flow. After the topmost bank of heating surfaces, the flue gas is redirected to the downward open-pass duct and distributed across the two flue-gas air heaters to preheat the combustion air. After flowing through these heat exchangers, the flue gas – cooled from about 350°C to about 160°C – is conducted in two parallel lines to flue gas cleaning systems.
A portion of the hot flue gas at immediate upstream of horizontal tubes banks is conducted via the recirculation shaft to the mills for lignite drying and transport.
The combustion process produces ash and combustion gases. Around 20% of the ash produced falls to the bottom ash hopper as bottom ash and the rest, around 80%, is entrained with the combustion gases as flyash. The combustion gases must be treated before exiting the exhaust stack to remove air pollutants such as particulates and sulfur dioxide (SO_2). The Air Pollution Control systems include fabric filters (FF) or electrostatic precipitators (ESP) for particulate control (fly ash), and a Flue Gas Desulfurization (FGD) system for removal of SO_2.

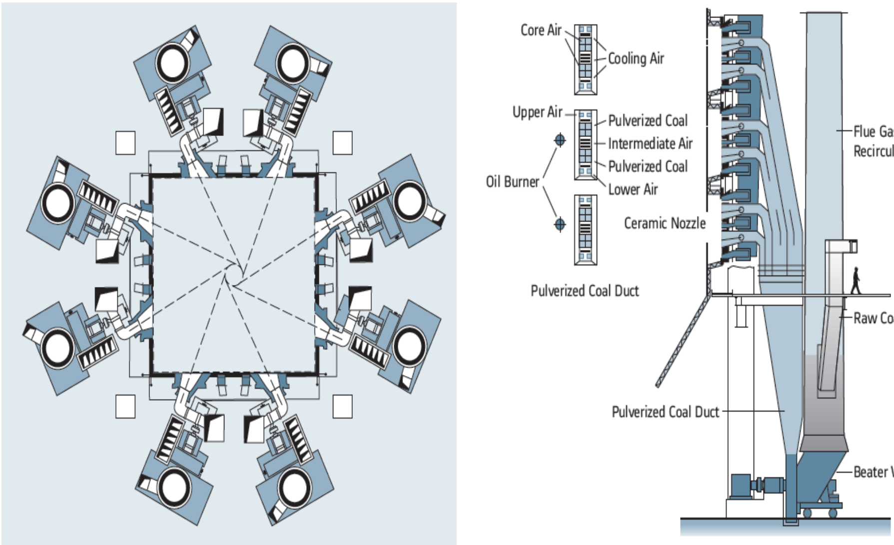
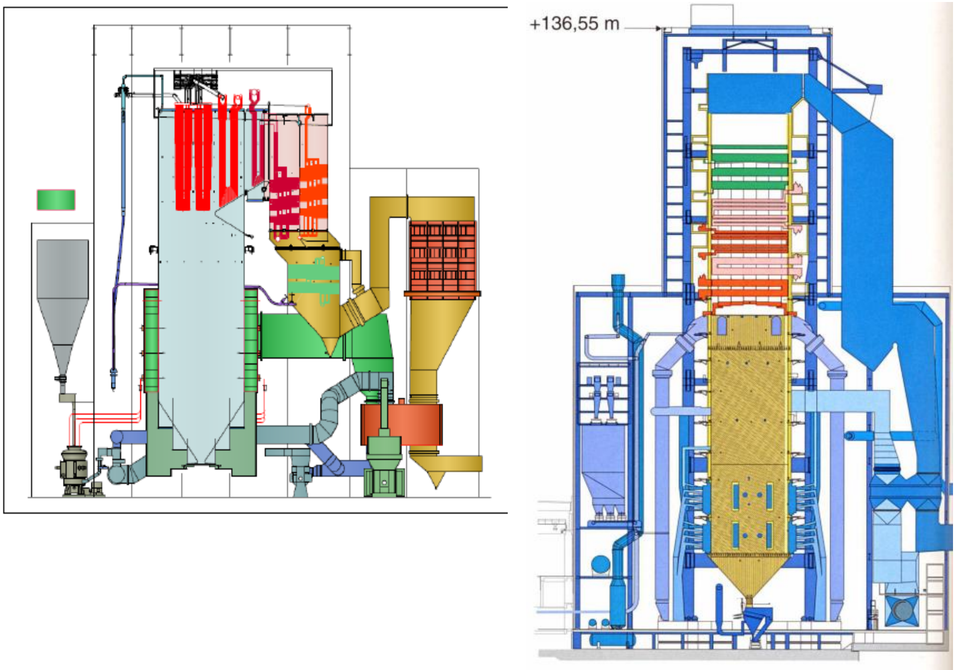


Figure **Error! No text of specified style in document.**-6 Burner and mill arrangement of a lignite fired boiler (From Alstom Power)

Boiler type and water-steam process

PC boilers can be two-pass type or tower type, as illustrated in Figure 6-7. These types differ in the arrangement of the upper heating surfaces. In a two-pass type boiler, the gas path consists of a horizontal section and a downward section. The upper heating surfaces are arranged on the top of the furnace and in the horizontal gas path in the form of pendant panels, and in the downward gas path in the form of horizontal panels. On the contrary, a tower type boiler uses the horizontal arrangement of superheater and reheater surfaces in the top of the furnace.

Each of these types has its own advantages, and each allows customer preference as a factor in the final arrangement of heating surface.



(a) (b)

Figure **Error! No text of specified style in document.**-7 Two-pass (a) and tower (b) type boiler

The tower design originally was developed for lignite-fired boilers, in which the asymmetric temperature distribution of the flue gas side and the high slagging tendency of the fuel intensified the problems of the two-pass boiler associated stresses caused by different temperatures of the waterwalls and the more complex structural design of two-pass boilers. Over time, the tower-type design has proved itself as the most suitable design for lignite firing, and in fact has dominated lignite-fired boilers. The most outstanding references of this design include lignite-fired units in Niederaussem and Neurath in Germany, Belchatow in Poland (**Table 6-6, 6-7, 6-8**). It should be noted that these boilers are the most modern and largest capacity lignite-fired boilers that have ever constructed so far, and Neurath Units F&G is said to have set new benchmarks in efficiency and emissions.

Besides the other known advantages, tower units offer special advantages for lignite firing:

- Arrangement advantages, because it supports the symmetrical arrangement of the gas recirculation ducts

- Less temperature and flue gas velocity imbalances, because no change of the flue gas flow occurs in an area including heating surfaces
- Easier cleaning of the heating surfaces, because the transverse pitch of the convective heating surfaces increases from the top to the bottom of the boiler, allowing the removed ash to fall into the hopper without being trapped in the heating surfaces underneath
- Simple and symmetrical hanging and support structure, without the need for expansion joints between heating surfaces, especially for large-capacity boilers

For all the advantages introduced, tower type boiler units are foreseen for this project.

Table **Error! No text of specified style in document.**-6 Niederaussem, Germany

Capacity	1x1,000MW
Technology	PC, supercritical
Main Steam Parameters	275 bar, 580^{o}C
Commissioning Year	2003
Fuel	Lignite
Fuel Specification	50% moisture
Plant efficiency	Approx. 43%
NOx emission	<200mg/Nm^{3} dry at 6%O2

Table **Error! No text of specified style in document.**-7 Neurath F&G, Germany

Capacity	2x1,100MW
Technology	PC, ultra-supercritical
Main Steam Parameters	272 bar, 600/605^{o}C (reheat)
Commissioning Year	2012
Fuel	High moisture lignite
Fuel Specification	Moisture: 50% guaranteed, 58% maximum
Plant efficiency	Approx. 44%
NOx emission	<200mg/Nm^{3} dry at 6%O2

Table **Error! No text of specified style in document.**-8 Belchatow, Poland

Capacity	1x858MW
Technology	PC, supercritical
Main Steam Parameters	275 bar, 550/580^{o}C (reheat)
Commissioning Year	2010
Fuel	Low grade Polish lignite
Fuel Specification	50% moisture
Plant efficiency	Approx. 42%
NOx emission	<200mg/Nm^{3} dry at 6%O2

6.6 Water-steam process

The boilers will be a once-through type. Feedwater at 343 bar/305°C is fed by electrically-driven boiler feed pumps to the boiler at the economizer. When consecutively passing through the economiser, water walls, start-up separator and superheaters, the temperature of the liquid (water/steam) continuously increases. At the boiler outlet, the main steam has a pressure of 275 bar and a temperature of 600°C. The main steam is initially expanded in the turbine's high-pressure section and conducted back to the boiler for reheating. At the inlet of the reheater, it has a temperature of 364.4°C and pressure of 62.1 bar. The reheater brings its temperature to 621°C at the outlet. The reheat steam is conducted to the intermediate-pressure section of the turbine.

Features of the boilers

The design of the **steam generator** will be specified according to common standard high reliability and soundness proven in many cases.

The pressure parts (walls and suspended heating surface) are completely welded and suspended in the supporting steel structure.

The firing system will be a direct pulverized coal (PC) firing with an ash removal.

The heat developed by the coal combustion produces high pressurized steam in an once-through boiler, with adequate supercritical live steam pressures and temperatures. The reliability of this heat transfer system has been proven in many countries in the world for many years.

The boiler will be specified in such way that reliable operation without back-up firing at a minimum capacity of 40% is possible. In line with the plant design the boiler can be operated with modified sliding pressure in the 60 –100 % load range.

The air and flue gas system consists of one set of forced draft fan, one set of regenerative air heater, one induced draft fan and one set of primary air fan.

The boiler will be designed for a steam generating availability period of 8000 hours per year, which is in line with common figures.

Pulverizer

The design includes pulverizers (or mills) that have the capacity to deliver the required size and quantity of coal to achieve full load operation with one mill out of the service (n-1 concept), which is a common and acceptable concept. Beater mills (or fan mills) will be used.

The mills receive the coal from the extraction of the coal bunkers. Coal pipes lead the pulverized coal to the burners.

Coal Burners

To achieve efficient fuel combustion with minimal release of NO_x and carbon monoxide, low NO_x pulverized coal burners are necessary. The burners are installed in the furnace wall at different levels. A defined number of burners are associated to one mill. If a mill is started or stopped, the corresponding burner group is operated or closed.

Overfire Air System
To provide additional NO_x emission reduction, overfire airports are provided above each column of burners. The ports are sized to compliment the low NO_x burners and maintain proper mixing velocities during this final stage of the combustion process.

Bottom ash removing
The burnt coal falls at furnace bottom in hopper filled with water. A submerged scraper conveyor removes the ash from the hopper into wet ash bunker.

Economizer
Feedwater is introduced into the unit through the economizer which is positioned at the bottom of the heat recovery flue.

Evaporator
The furnace consists of a lower section with vertical or spiral tube wall design. The furnace enclosure tube size and spacing are selected to provide a “natural circulation” flow characteristic to accommodate radial heat absorption variations around the perimeter of the furnace. Tube sizes and spacing, membrane fin sizes and materials are in general selected to provide for base load condition as well as defined cyclic operation of the plant. The final evaporator zone forms the furnace nose.

Superheaters
From the steam/water separators the steam passes through the superheater circuitry which includes the furnace roof, the heat recovery area enclosure and part of the sidewalls. Spray water attemperators are positioned upstream of the superheaters for final main steam temperature control.

Reheater
The reheater tubes are placed in the heat recovery flue and then extended into the vestibule area to achieve the final reheat steam temperature.

Sampling system
A sampling system to allow for monitoring of the boiler water/ steam properties.

Safety valves
Safety valves of approved types are equipped at the outlet of the final superheater and reheater for over pressure protection of the boiler.

Sootblowers
An automatic steam operated soot blowing equipment will clean boiler furnace and flue gas passages while the steam generator is in operation. This ensures a nearly constant heat transfer for the hot gas through pipe wall to water or steam in the heat recovery section of the steam generator.

Insulation
Thermal insulation (brick work or layers of adequate material) will prevent an undue heat loss at furnace walls and hot flue gas ducts.

Forced draft fan
Air is taken from the ambience and pressed via air boxes surrounding the boiler walls into the furnace. Primary air (PA, 2x50%) is required for the burners, secondary air (SA, 2x50%) for control of temperature in the furnace over the burners and for NO_x reduction.

Regenerative air heater
After the FD fan, the air is warmed up in a horizontal rotor with heat from the flue gas. The system has to be properly designed and manufactured to reduce leakage of air to flue gas side.

Induced draft fan
The flue gas is drawn from the furnace through the steam generator, rotary air preheater and flue gas desulphurization and precipitator to the chimney. The ID fan is placed after the precipitator. It is controlled so that the furnace is under pressure during all operation conditions.
There are two possible configurations with their specific advantages and disadvantages. On the one hand a single ID fan is cost-optimized and easier to handle during operation. On the other hand double ID fans provide a more flexible operation and in case of trip of one fan the unit can continue to operate with half load. Both systems are common for in coal fired power plants with similar capacity; nevertheless there is a trend to choose the double configuration. In any case respective spare parts should be on stock to avoid long unit outages in case of failures of one of these equipments. As both systems are proven technology the selection can be made according to the preferred system of the owner or contractor.
The ID and FD fans are normal designed and will have sufficient reserves for pressure drop and volume flow (110% flow reserve, 121% pressure drop).
For start-up and shutdown a **fuel oil system** will be installed. The fuel oil supply system will provide a sufficient storage capacity (60 hours oil firing).
The necessary steam during start-up of the coal-fired boiler (steam supply for fuel oil atomization, feed water preheating, etc.) will be provided by an oil fired **auxiliary steam generator**.

Steel Structure
Boiler house steel structure forms, together with boiler supporting structure, one static system, transferring all static loads from external climatic effects (wind, seismic, etc.), loads from technological equipment and its own weight into foundation.
The steam generator proper (evaporator walls, super heater and reheater) hangs in the boiler steel frame. The ash system under the furnace is placed on the ground, so that the steam generator can expand downward in a water ring over the ash removal system.

6.7 Flue gas and ash treatment Technology

NOx suppression

The Nox formed in the furnace of a PC fired boiler can be reduced by primary (in-combustion) and secondary (post-combustion) measures.

Secondary Nox reduction measures involve ammonia injection and the use of catalysts and have been fitted successfully upstream or downstream of the airheaters and electrostatic precipitators.

The aim of primary measures is to reduce Nox formation in the combustion process directly in the furnace, i.e. to ensure that as little Nox as possible is produced, so that secondary measures which require very costly equipment and consumables might not needed to ensure emission compliance. The possible primary measures include:

- Reduction in excess air
- Air staging across combustion chamber height
- Vertical fuel staging across burner height
- Flue gas recirculation (cold flue gases downstream of air pre-heater are recirculated to combustion chamber)
- Finer coal milling
- Low-Nox burner: The most important design of the low Nox burner lay out is characterised by concentration of fuel and graduation of air to get a controlled combustion avoiding the production of Nox

These measures counteract the formation of Nox. The intensity and timescale of the mixing of fuel and air is reduced, which results in longer residence times of the fuel particles within a reducing environment. Air staging across the combustion chamber height ensures that air is only supplied when it is needed for combustion of the fuel particles. This keeps the combustion temperature as low as possible. Finer coal milling reduces the size of the fuel particles and reduces the required time for burnout in the combustion chamber.

The primary measures have been installed in lignite fired power plant and has been demonstrated to successfully meet the requirement of the regulations.

The Nox emissions depend on the boiler and combustion system design as well as the fuels. Lignite have very low fuel ratios and high moisture content which have positive impacts on Nox formation, furthermore, the large boilers minimise thermal Nox production. For most modern lignite-fired units where constant monitoring and adjustment of the lignite and air feed and optimization of combustion process are conducted, Nox emissions of less than 0.16 lb/MMBTU (200mg/Nm^3) at 6% O2, dry, are obtained with primary measures alone. This has been witnessed in various units including those in Niederaussem and Neurath in Germany.

Considering Nox emission limits stipulated in both Indonesian regulations and IFC guidelines, secondary measures for further reduction of Nox emission are not foreseen for this project. The primary measures shall be used.

SO2 removal

Although the calcium-based chemicals in coal ash contribute to some extent to self-desulfurization, it is very likely that the SO2 emission will exceed the norms stipulated by the Environment Controlling Authority of Indonesia, and limits suggested in IFC guidelines, without post-combustion desulfurization.
Post-combustion desulfurization, therefore, is foreseen.
There are three technologies available at the market:

- Wet limestone process
- Dry & semi-dry lime process
- Seawater process

In the wet limestone process, SO_2 is removed almost stoichiometrically (Ca/S ratio in the order of 1.05 to 1.10) in a diluted limestone slurry solution, $CaSO_3$ is formed in the wet scrubber. This solution must be oxidized to convert $CaSO_3$ to $CaSO_4$ and dewatered afterwards to gain usable gypsum. Otherwise it may be used in the ash handling process to be discharged with the ash.

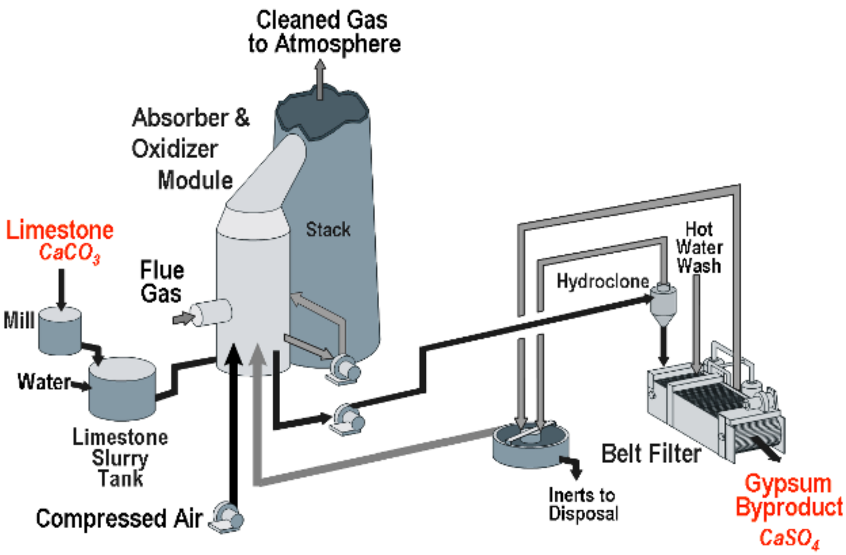


Figure **Error! No text of specified style in document.**-8 Wet limestone process

The lime processes are based on the reaction between lime and SO2 in the flue gas. The lime-based reagent is injected in the form of milk of lime (in the case of lime spray dryer or semi-dry process) or (humidified) powder (in case of dry processes). The heat of the flue gas dries up the solids and the reaction product is collected by downstream dedusting equipment.
The seawater process uses natural alkalinity of seawater as reagent for desulfurization. The process is based on the following chemical reaction:

$$SO_2 + 2HCO_3^- + \frac{1}{2}O_2 \rightarrow SO_4^{2-} + 2CO_2 + H_2O$$

The seawater process can be used in power plants where seawater is used for cooling the condensers. In such power plants, cooling seawater downstream of the condensers is routed to the scrubbers for capturing sulphur dioxide.
The seawater process cannot be used for this project site, while the wet limestone process is a proven technology and has been most widely used in various parts of the world.

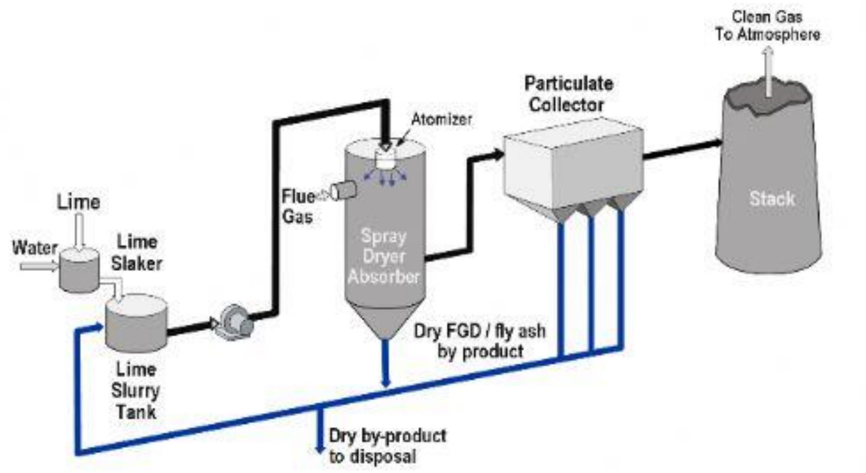


Figure **Error! No text of specified style in document.**-9 Semi-dry lime process

Flue Gas Desulphurization System
The flue gas coming from the ID fan after the ESPs of each boiler is united to a common flue gas duct and routed to the absorber system. Then the flue gas will be desulphurized in a spray tower (absorber) using the wet limestone process with forced oxidation. No reheating system will be required. The applied FGD process will be wet process with limestone producing dehydrated gypsum ($CaSO_4$ x$2H_2O$) at 10% moisture as by-product.
Considering a low SO2 removal level of around 50% to meet the emission limit, it is foreseen that only a portion of flue gas flow will be treated in the scrubber system, and the rest will be bypassed.
The FGD designed as a wet scrubber plant will mainly consist of:

- limestone milling
- sorbent preparation
- absorber
- sorbent circulation
- gypsum dewatering with vacuum belt filters and conveyor belt
- slop (discharge) tank.

The wet limestone slurry process is designed to involve sulphur dioxide (SO_2) and hydrogen chloride (HCL) being precipitated in an alkaline scrubbing liquid.

The absorber vessel consists of various spray nozzle rows to evenly distribute the lime slurry in the flue gas stream. Following this process stage, the flue gas can be emitted directly to the atmosphere via a separate stack on the absorber or via a cooling tower (mainly greenfield installations). A typical flow diagram of a wet type FGD process is shown in Figure 6-10.

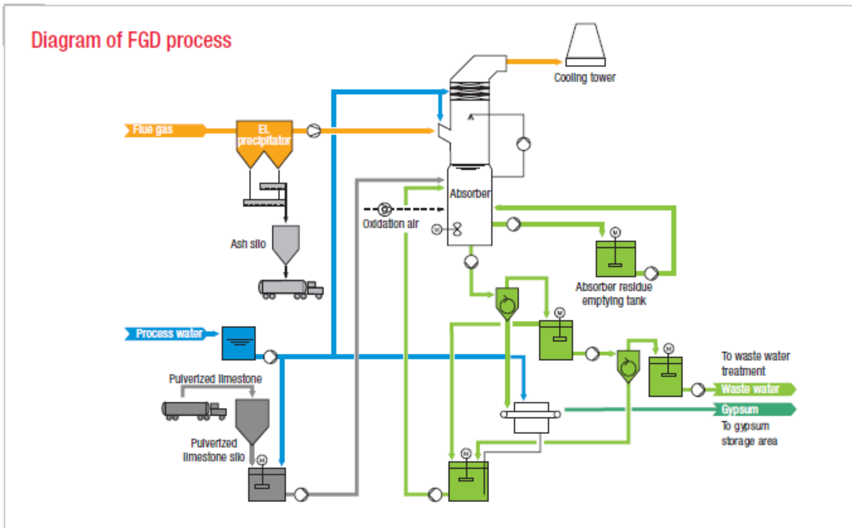


Figure **Error! No text of specified style in document.**-10 Flue gas desulfurization diagram

The absorber vessel will be made of steel with suitable rubber lining or with other anti-corrosion measures. Each circulation pump has to provide one single spray level, without standby pump. A part of the absorber slurry is pumped to a set of hydro cyclones. Gypsum slurry and waste water will be removed from the process. A gypsum dewatering system (2 vacuum belt filters and ancillary equipment) down to water content of 10% in the gypsum shall be installed. The whole absorber area including the limestone preparation will be drained into the FGD drain pit to ensure collection of each kind of leakage. Thereby it is possible to empty the drain pit alternatively into the blowdown tank or directly into the absorber sump.

All pipelines connected to a rinsing system will be supplied from the process water system and all necessary drives will be connected to an emergency electricity supply system. The flue gas leaving the reaction zone carries aerosols and water droplets which shall be removed in mist eliminators. The mist eliminators shall be sprayed with process water to avoid fouling. The clean gas will not be reheated. In order to avoid corrosion, all ducts and the stack pipes (one common stack with two pipes) will be covered by means for corrosion avoidance.

The gypsum slurry from the wet scrubbers will be pumped to vacuum belt filters. From these filters the gypsum with a moisture of about 10% will be transported to a gypsum storage and then by belt conveyors to the ash disposal area. As an alternative the gypsum can be transported to a truck loading station.

Output of the process, gypsum, is a product whose marketability in Indonesia may be evaluated that it might be sold instead of being disposed.

6.8 Particulate removal from flue gases

Flyash-laden flue gas needs to be treated in dust collectors before exiting it to the chimney. The types of dust collectors include:

- Inertial separators
- Wet scrubbers
- Fabric filters
- Electrostatic precipitators

Inertial separators separate dust from gas streams using a combination of forces, such as centrifugal, gravitational, and inertial. These forces move the dust to an area where the forces exerted by the gas stream are minimal. The separated dust is moved by gravity into a hopper, where it is temporarily stored.

Dust collectors that use liquid are known as wet scrubbers. In these systems, the scrubbing liquid (usually water) comes into contact with a gas stream containing dust particles. Greater contact of the gas and liquid streams yields higher dust removal efficiency. Fabric filters, commonly known as bag houses, use filtration to separate dust particulates from the flue gas. Dust-laden gases enter the bag house and pass through fabric bags that act as filters. The bags can be of woven or felted cotton, synthetic, or glass-fibre material in either a tube or envelope shape.

Electrostatic precipitators use electrostatic forces to separate dust particles from exhaust gases. A number of high-voltage, direct-current discharge electrodes are placed between grounded collecting electrodes. The contaminated gases flow through the passage formed by the discharge and collecting electrodes. Electrostatic precipitators operate on the same principle as home "Ionic" air purifiers.

The airborne particles receive a negative charge as they pass through the ionized field between the electrodes. These charged particles are then attracted to a grounded or positively charged electrode and adhere to it.

The collected material on the electrodes is removed by rapping or vibrating the collecting electrodes either continuously or at a predetermined interval. Cleaning a precipitator can usually be done without interrupting the airflow.

The dust collecting efficiency of inertial separators and wet scrubbers is not high enough, so they normally are not used in modern coal-fired power plant in the context of increasingly stringent emission limits.

In the meanwhile, fabric filters and electrostatic precipitators have been widely used not only for coal-fired power plants but also for other industries (cement, steel, etc.). High efficiencies, as high as 99.9%, allow clean flue gas to as low as 30mg/Nm^3 particulates required in the most stringent emission standards

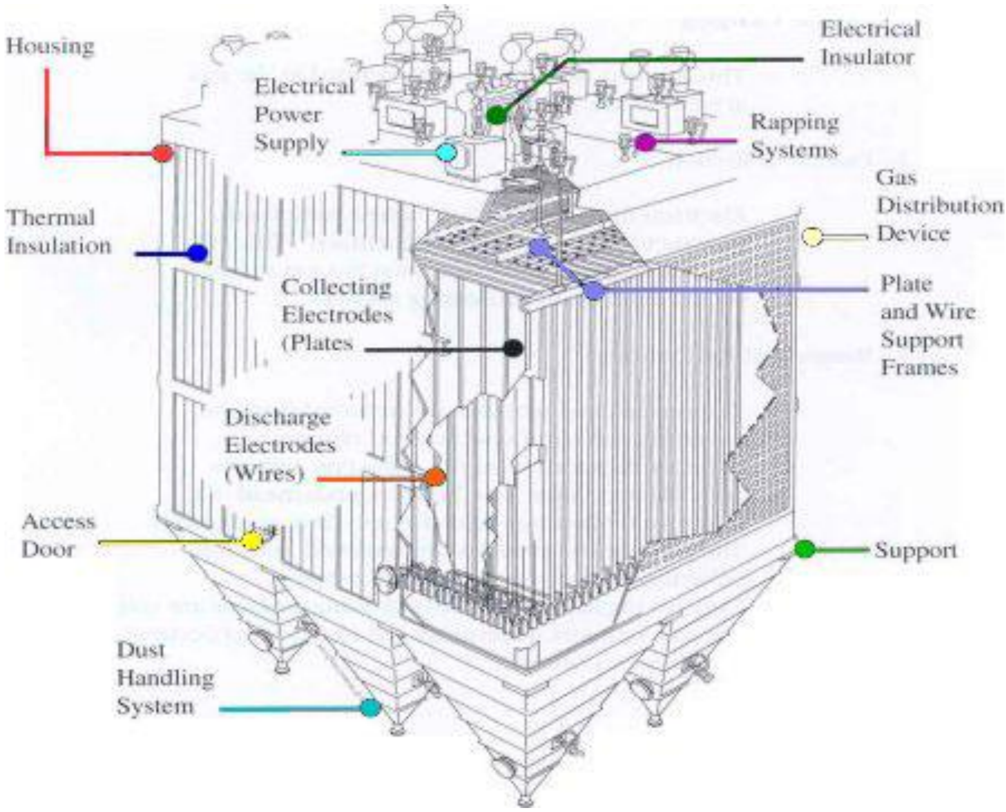


Figure **Error! No text of specified style in document.-**11 Electrostatic precipitator (source: Neuendorfer knowledge base)

Electrostatic Precipitator (ESP)

The dust laden flue gas is entering the ESPs and the particulates are removed from the flue gas. The ESP will be designed as 2x50% with a dust collection measured at the outlet of <50 mg/Nm^3 (dry flue gas, 6% O_2 content) with coal firing in the specified range. By using a modern type of ESPs the collecting efficiency will be sufficient to cover all normal conditions including worst coal and soot blowing.
The flue gas temperature downstream the boiler will be in the order of 160°C. According to the SO2-content in the raw gas of about 1,700 mg/m^3 and with a conversation rate from SO2 to SO3 of about 3% the SO_3 content in the flue gas will be around 65mg/m^3. With moisture content of the flue gas of about 22% by volume or 14% by weight, the H_2SO_4 dew point will be in the order of 148°C when the boiler operate at full load. Considering H_2SO_4 condensation that can occur at low loads, the use of enamelled heating surfaces at the cold end of the preheater may be recommendable. However, all parts of the flue gas treatment plant have to be designed with sufficient corrosion protection.

6.9 Water-Steam Cycle System

Process description

The water-steam cycle consists of the steam turbine as the central component, the feedwater heaters (low-pressure and high-pressure), the feedwater tank with deaerator, the condensate extraction pumps, the boiler feedwater pumps and the boiler proper. The superheated steam generated in the boiler will be expanded in a single reheat steam turbine (one per unit). The steam turbine will consist of one (1) high pressure turbine, one (1) intermediate-pressure turbine and one (1) double-flow low pressure turbine.Some steam is extracted from the turbine for purposes of deaeration and feedwater/ condensate preheating. The exhaust steam of the turbine is condensed in an water-cooled condenser. The condensate from the condenser will be pumped by means of 2x100% main condensate pumps to the deaerator/ feedwater tank. The function of the deaerator is to eliminate the oxygen in the water-steam cycle.

The condensate will be heated up by means of a gland steam condenser and four low pressure heaters. After deaeration, the feedwater will be pumped by means of 2x100% feed water pumps via three high pressure feedwater preheaters to the boiler economizer. Condensate losses and boiler blow-down are compensated by make-up water (demineralized water), which is fed to the system into the deaerator.

A steam turbine bypass system consisting of 2x30% HP and LP bypass stations will be installed to cover start-up/shutdown turbine trips and house-load run-back requirements.

An auxiliary steam boiler (1x100%) for two power plant units will be installed to provide steam during start-up, low load or trip. The auxiliary steam system is mainly required for warming up/deaeration of the feedwater and for the provision of gland steam of the turbine.

Condensate/ boiler feed water in the water steam cycle must be treated with either all-volatile or oxygenated treatment (to be proposed by EPC contractor) to avoid corrosions.

In the case of all-volatile treatment, the following concept has been laid down:

- For all-volatile treatment (reducing) or AVT(R) method, dosing of ammonia (alkaline solution) and hydrazine (or another acceptable substitute) into the condensate and/or feed water
- For all-volatile treatment (oxydizing) or AVT(O), dosing of ammonia into the condensate.

In the case of oxygenated treatment, ammonia and oxygen are dosed into the condensate.

7 AUXILIARY SYSTEM FOR LIGNITE COAL FIRED POWER PLANT

7.1 Coal Handling System

Because the power plant shall operate as a mine mouth plant, the lignite coal shall be excavated in mining field and transported to the entrance of the stockpiling and mixing yard, common for all power plant units. The further equipment of the lignite handling system is the stacking and relaiming equipment, crusher plant, belt conveyors to the power plant units, feeding system of the bunker bins in the individual units and the bins itself. Two coal handling lines, each of a minimum 100 % capacity shall transport the lignite from the transfer point to the storage stockpiles and then to the crusher building, and from there to the mill bunkers, so that one line shall be considered as a complete stand by line. In the event coal quality is suitable, it can be transported directly to the crusher building and then the mill bunkers, bypassing the stockpiles. In designing the coal handling system, maximum coal demand and the worst fuel shall be considered.

In region of the coal handling system, such as transfer points, the crushers, screen, etc, the dust emission shall be kept as low as possible by using appropriate devices such as dust-proof casings, water spray or suction devices. A belt scale and automatic as-received sampling system is provided for certification of coal quantity and quality. The belt scale is installed on the receiving conveyor. The as-received sampling system and stockyard feed conveyor transfer chutes are located in a transfer house designed to accommodate the equipment and provide adequate space for maintenance.

Coal from the live stockpile is moved by mobile equipment to and from the adjacent dead coal stockpile for use if coal supply is disrupted. There is a reclaim hopper beneath the live coal stockpile with variable speed vibrating feeder. One reclaim conveyor supplies adequate coal to the silos via a crushing plant. The bidder may also propose other alternative system for the coal feeding.

A self cleaning magnetic separator is installed over the head pulley of the conveyor to prevent damage to the downstream equipment. The magnetic separators, and coal transfer chutes, are sized to accommodate the equipment and provide adequate space around the equipment for maintenance. To verify the type and quantity of coal being fed to the boilers, the reclaim conveyor is equipped with belt scales and an as-fired automatic sampling system. The belt scales are also used to control the feed rate to prevent overloading and subsequent spillage. The as-fired automatic sampling system, magnetic separator, and transfer chutes from the reclaim conveyor to the silo distribution tripper conveyors are housed in a transfer tower. Coal is transferred to the silos by traveling trippers.

The coal handling system is controlled from the coal handling control room adjacent to the transfer house. The overall control is programmable by a logic controller system. The control board including the controls, graphic display (mimic), and communicator sections to allow remote operation of the coal handling system. The central coal handling building also houses the necessary electrical equipment to distribute power to the coal handling equipment.
Transfer points in transfer towers are provided with dust suppression water spray to keep dust to a minimum. Discharge points in the receiving and reclaim hoppers and at the telescopic chute also are provided with dust suppression spray water to limit dust during discharge from the vibrating feeder and subsequent conveyers transfer points.
The belt conveyors leaving the mines, and from the transfer point to boiler bunkers shall consist of two lines designed preferably as redundant system. The conveyors shall have a minimum capacity of coal transport to fill the stock pile in relatively short time. The capacity shall surplus the actual coal need of the plant by far.
At the transfer point at the storage stockyard the incoming conveyors shall feed the conveyors in the stockyard and shall have a crossover passage to the conveyor belts in the stockpile.

Coal storage and mixing yard

The coal handling system of the power plant system begins at the transfer point with a weighing device and sampling equipment.
The stockpiling of lignite will be done by one rail-mounted bucket-wheel type stacker/reclaimer for each conveyor line.
The coal storage facility will consist of two covered and one open stockpiles arranged in parallel, and be equipped with rail-mounted stackers and reclaimers as required. Stacker-reclaimers that combine both stacking and reclaiming functions can also be used. The dry stockpling is needed to reduce the moisture of lignite and/or prevent it to catch more moisture especially during the rainy season, which will contribute to increasing the boiler efficiency. The stockpiles shall have a capacity of minimum 20 days of full load operation of the plant for:

- Balancing the difference between the constant demands of the power station and the varying lignite supply from the opencast mine,
- Securing a constant lignite supply to the power station when the lignite transport from the mine would be interrupted from time to time, especially during hard conditions
- Homogenization of the lignite for the power station (see following chapter)

The conveyors, which are equipped with metal detecting devices, shall be furnished with textile cord belts. Coal yard ground conveyors are equipped with water removal system.
The reclaiming of lignite from the stockpiles will be undertaken by the rail-mounted reclaimers, which load the belt conveyors towards the crusher building. A direct supply to the crusher plant can be done if the quality of lignite supplied from the mines is suitable.

Dewatering of the coal stock pile has to be permanent and "black water" will be led into a separation basin. Coal dust settled in the basin can be added to coal feeders into the bunkers, the water can will be sent to Waste Water Treatment System.
A water spray system shall be installed for dust surpression and to prevent the lignite from unintentional drying during prolonged storage periods. Additional a Fire Fighting system installation will be installed to suppress spontaneous lignite combusion that may ocur. If the lignite would dry out it would become highly inflammable and the handling risk would increase. Temperature and/or fire detection equipment will also be required.

Coal blending procedure
The lignite coal for the power station, which shows considerable differences in the calorific value and other contents, will be homogenized by stacking the raw lignite coal in different rows and reclaiming it by stackers and reclaimers.
For the purpose of blending, the stacking will be possible spreading the coal in Chevron mode (layer by layer) or Windrow mode (row by row). In both operation modes the bucket wheel reclaimer lifts the coal in cross-section of a row.
For the purpose of blending the coal as well, the bucket-wheel reclaimers will be capable of reclaiming in block system by two-slice operation.

Coal bunker bins
The coal shall be transported by the conveyors up to the mill bunker bins in all power plant units. The capacity of conveyors and all equipment for the transfer of coal from the stockpiles up to the mill bunkers shall be so designed that all steam generator units can be fed without any difficulties and interruption. The conveyors over the bunkers' opening shall have scrapers to fill each mill bunker. Alternatively movable and reversible belt conveyors shall be installed.

7.2 Fuel oil handling system
The light fuel oil (LFO) shall be utilized as start-up and support fuel for the burners of the two boilers. In addition the fuel oil tanks and dedicated pumps shall also supply the emergency diesel generator, the auxiliary boilers, the diesel driven fire fighting pumps and the trucks with LFO. The fuel oil will be delivered to the project site by fuel oil tankers. At the truck unloading station the LFO will be pumped into the fuel oil storage tanks.
The LFO system will consist of:
- truck unloading station
- 2 x 100% unloading pumps with filters
- 2 storage tanks with fuel oil retention basin
- 4 x 33% forwarding pumps for 2 boilers
- 2 x 100% forwarding pumps for remaining consumers
- truck filling station for two trucks
- piping system

The storage capacity will mainly depend on the number of boiler start-ups per year. For a base load scenario about 16 starts per year have been assumed.

7.3 Limestone handling system

Limestone will be delivered to the project site by trucks. The trucks will transport the limestone to an open limestone storage area covering about 30 days of total limestone demand for two units (based on reference coal). The distribution from the conveyor to the storage area will be achieved by a unloading tripper running above the stockyard. Bulldozers and front-end wheel loaders will be set in the limestone yard for pushing limestone piles and for pushing into the underground hoppers. Beneath the underground hoppers belt feeders will transport the limestone to 2x100% limestone conveyors (belt conveyors). The conveyors will convey the limestone to redundant screening and coarse crushing system (2x100%). The pre-crushed limestone will be transported to limestone storage silos. Downstream of the silos a redundant screening and fine crushing system (2x100%) is installed to meet the required limestone particle sizes (about 100 - 250 µm). A 2x100% pneumatic conveying system will convey the limestone powder to the limestone day bunkers arranged close to the FGD.

7.4 Ash Handling System

The ash handling system includes both fly ash and bottom ash system. This system conveys the ash to a common storage silo, from which the ash is transported by truck.

Fly Ash System

A single fly ash silo is provided for the Units. The silo has storage capacity for minimum 36 hours at full load. The fly ash system removes the ash that accumulates in the electrostatic precipitator and the economizer hoppers using a pneumatic vacuum conveying system sized for approximately twice the expected ash quantities. The fly ash silo is provided with a single dry unloading chute and a single batch mixer to condition the fly ash before it is discharged via a telescoping chute into the truck for transportation to the storage area. Additional dust suppression equipment will be employed as necessary to further control fugitive dust.

Bottom Ash System

Each boiler shall be provided with a suitable bottom ash extraction system and provision for cooling .it before storing in a bottom ash hopper. From the ash - hopper, bottom ash is cleared by pneumatic ash handling system.

Ash storage facility

The ash will be transported to specific ash storage sections and then distributed evenly by means of bull dozers. Appropriate dust suppression systems will be installed to avoid dust emissions into the atmosphere. In order to further minimize the water demand for dust suppression it is intent to limit the size of the ash storage sections. After one month the filled ash storage sections will be covered with rocks and stones from the construction area or from nearby mines, which enables a good surface protection against dust emissions and minimizes the spray water demand.

In order to avoid contamination of ground water an appropriate sealing system (layer of geotextile membrane) will be considered. The drainage of the ash storage will be collected in an ash drainage basin via drainage pipes arranged below the lining system. The ash drains will be reused for dust suppression.
If the ash production cannot be utilized and will be discharged entirely to the ash pond, the land area allocated for the ash yard (approx. 110ha) can be sufficient only with ash piles stacked up to 20 m height. To save the initial capital cost, a multiphase approach is considered as illustrated in below pictures. At the end of each phase, a new earth dyke will be constructed for the next phase. At the end of plant lifetime, the ash stockpile will be topped with a soil layer on which trees will be planted. This is an environment friendly solution. In phase 1, the ability to stack the total ash (fly ash, bottom ash and gypsum) over the first 10 operating years has been considered.

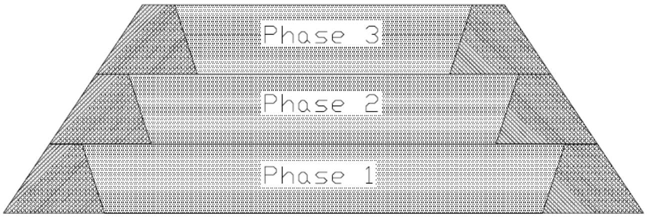


Figure 7-1 Multi-phase stacking of ash

The later phases may not be necessary, subject to the following conditions:

- The ash can be used as cement filler, brick making, and/or condstruction material
- The ash can be disposed to exhausted coal mines.

Investigations made recently indicate that ash can be placed at local markets as byproduct: flyash can be used as cement filler, fly/bottom ash can also be utilized as asphalt mix (ready mix), concrete mix and paving blocks, bricks

7.5 Cooling systems

Main cooling system

The energy of the steam can only partly be used for the generation of electricity. Therefore heat rejection is an essential part of the power plant process, as it discharges the non-usable part of the heat. The pressures in the condenser are in the millibar range and influence the steam cycle efficiency significantly. As better the cool end of the steam cycle can be realized, as higher is the plant efficiency. Cooling media are generally water or air, depending on water availability in the required mass or quality. The cooling alternatives not only differ in the influence to the steam cycle, but also in power consumption, usage of chemical additives and the investment and operation costs, which has to be considered in the cooling system selection and layout process.

- Wet type cooling system with:
  - Mechanical Draft Cooling Tower
  - Natural Draft Cooling Tower

- Heller Dry Cooling System with:

- Mechanical Draft Cooling Tower
- Natural Draft Cooling Tower

- Direct Air Cooled Condenser
- Indirect dry cooling system

This section shall give an overview about the operation of each system and the specific advantages and disadvantages.

Wet Cooling Systems

Wet cooling systems reject the heat from the steam circle in a surface condenser with cooling water, which is cooled down in a cooling tower by means of evaporation of a small part of the circulating water. The losses by evaporation and cooling tower blow down, which is needed to prevent a concentration of minerals in the cooling water, have to be filled up with make-up water continuously. The amount of make-up water depends on the losses by evaporation, drift and the quality of the water in the cooling cycle (blowdown). Sufficient water must be available all over the year to operate a plant with a wet cooling system. The cooling tower can be either natural draft or mechanical draft design.

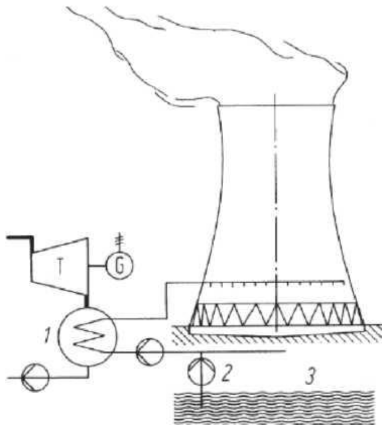


Figure 7-2 Wet Cooling system scheme, 1) Condenser, 2) Make-up line, 3) Water source (Source: DUBBEL)

There are two types of cooling towers, mechanical draft cooling tower (MDCT) and natural draft cooling tower (NDCT). In the MDCT movement of air through cooling tower by means of a fan or other mechanical devices while in NDCT the air movement is natural flow.

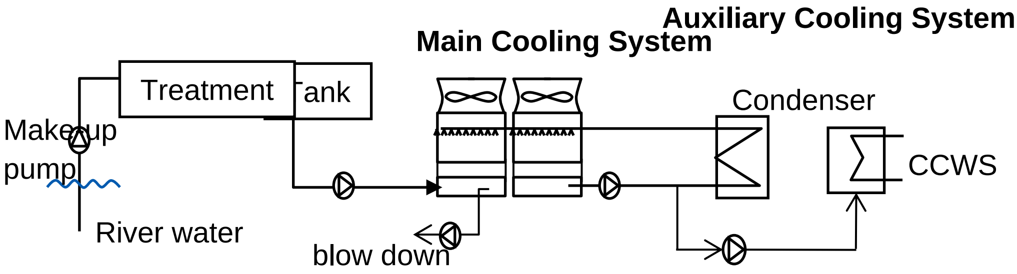


Figure 7-3: Mechanical draft cooling tower

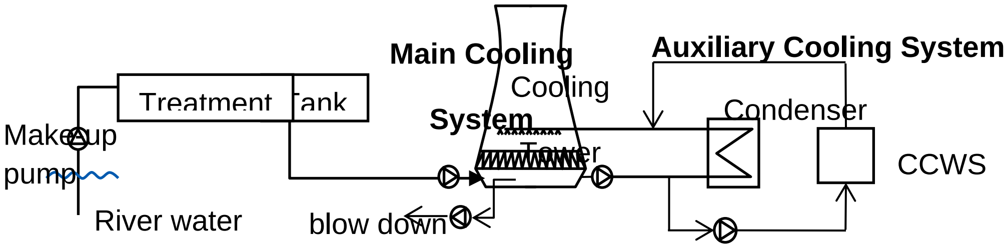


Figure 7-4 Natural draft cooling tower

Heller Cooling System

This system is invented by Professor Laszlo Heller in Hungary in the 1940's. In the Heller process only a fraction of the condensed water is extracted to serve as feed water for the steam cycle again, whereas the major part of the condensate is pumped through a dry air cooling tower to be cooled down by ambient air and injected later into the condenser again in order to precipitate the steam coming from the turbine exhaust.

In the return line from the cooling tower to the condenser the flow passes through a recovery turbine, which is installed to reduce the system's power consumption. The cooling tower can operate in mechanical draft or natural draft mode, though, the natural draft alternative is the more common application. A sprinkler system may be installed in the cooling tower to keep the efficiency decrease in hot ambient conditions on a low level by spraying water on the heat exchanger surface. **Figure 7.5** shows the process of the Heller cooling system.

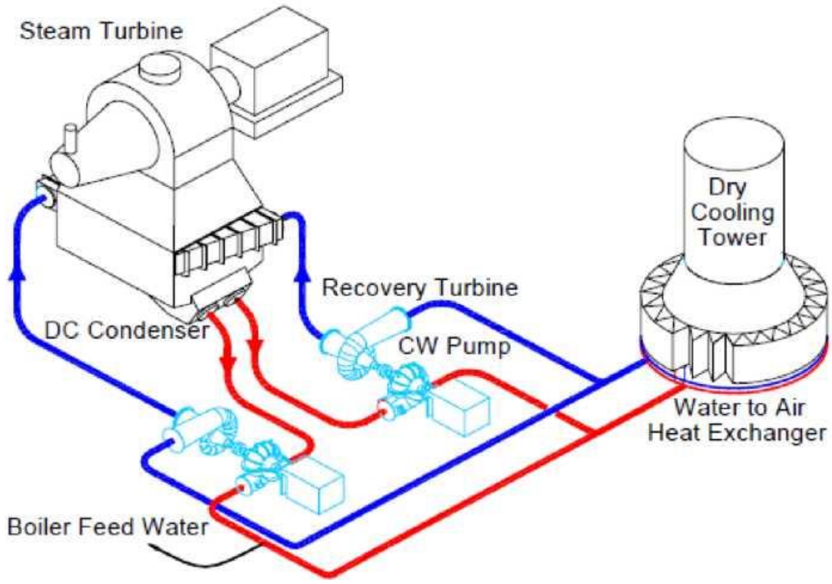


Figure 7-5 Heller Cooling system [source: The advanced Heller System - Technical features Characteristics by A. Balogh & Zoltan Szabo, 2005]

Air Cooled Condenser (ACC)

Steam from the turbine exhaust is led directly to the steam distribution tube on top of the ACC. Afterwards the steam is condensed while running down in finned tubes, working as heat exchangers. The tubes are generally arranged in “A” shape configuration, equipped with electrical driven fans at the bottom side providing a sufficient air flow through the pipe bundles.

The steam precipitates only partly (approximately 80%) in that section. The remaining uncondensed steam including the non-condensing gases rise again in the adjacent dephlegmator section, where the rest of the steam condenses. Unlike in the first section in the dephlegmator steam flow is upwards, while condensate flows downwards in order to collect and draw off the non-condensing gases at the top of the dephlegmator, whereas the condensate is collected at the bottom. The cooled condensate is pumped back to the feed water system by condensate pumps (Figure 7-6).

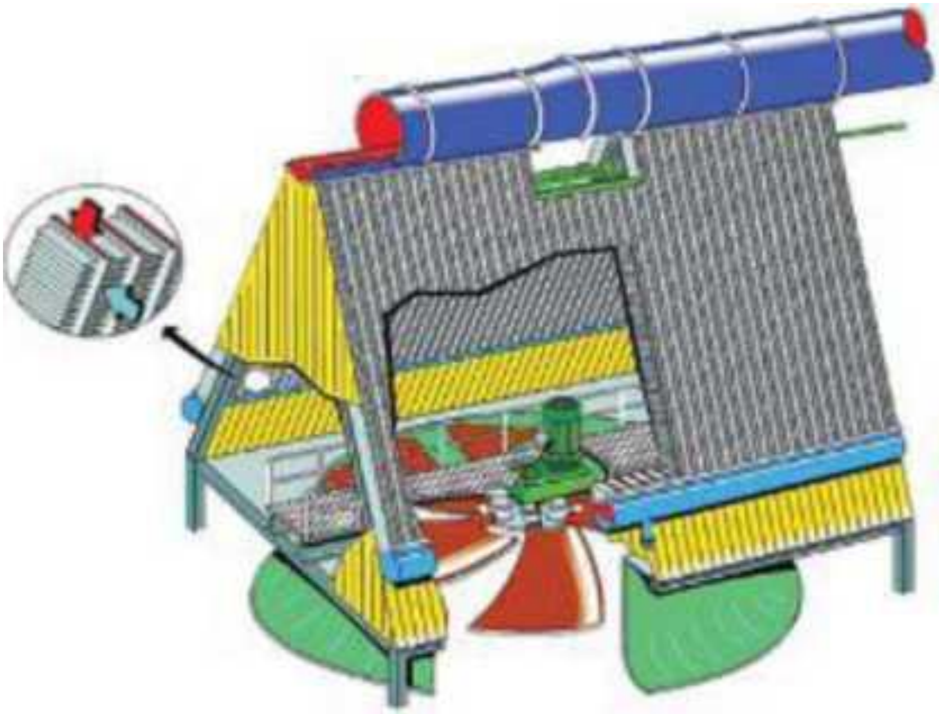


Figure 7-6 Structure of an Air Cooled Condenser [source: SPX Cooling]

Dry Cooling Tower

In dry cooling tower systems the heat rejection from the steam cycle takes place in a surface condenser like in wet cooling and once through cooling systems, whereas the cooling water is cooled down a closed cycle by air in the dry cooling tower instead of an open cycle. Dry Cooling towers are generally not applied as a main cooling system, but for auxiliary cooling and HVAC systems.

Figure 7-7 Mechanical Draft Dry Cooling Tower [source: Target Equipments]

Comparison of cooling systems

Besides the above mentioned influence on the steam cycle efficiency by defining the cold end temperature and the condenser pressure, the cooling systems differ in several other points. Especially power consumption, water consumption, flexibility in operation and investment cost are major points which have to be considered for the choice of the cooling system. The following Table 7-1 gives an overview of the characteristics of different cooling alternatives.

Table 7-1 Cooling systems - Comparison table

Parameter	Wet Cooling		Dry Cooling		
	NDCT	MDCT	ACC	Heller + NDCT	Heller + MDCT
Steam cycle efficiency (condenser pressure)	+	+++	-	-	-
Power consumption	0	-	--	++	-
Water consumption	-	-	++	++	++
Noise emission	+	-	-	+	-
Reliability	+	0	+	-	0

Parameter	Wet Cooling		Dry Cooling		
	NDCT	MDCT	ACC	Heller + NDCT	Heller + MDCT
Corrosion & fouling	0	-	+	+	+
Maintenance	+	-	-	0	-
Size (Plot Area)	-	+	--	--	-
Visual impact	-	+	-	-	+
Investment Cost	-	+	--	--	0
SUM	**4+, 4-**	**6+, 5-**	**4+, 10-**	**6+, 7-**	**4+, 5-**
Total	**0**	**1**	**-6**	**-1**	**-1**

Summing up, the mechanical draft cell cooling towers are considered most viable option.

Auxiliary cooling system

The auxiliary cooling water system is designed as closed loop and serves to transfer the heat dissipated by different components via water heat exchangers. The main consumers are:

- lube oil coolers for fans (PA; SA and IDF)
- turbine lube and control oil cooler
- feed water pumps (lubrication, sealing and motor cooling)
- condensate pumps (lubrication, sealing and motor cooling)
- generator water cooler (as applicable)
- transformer cooler
- air compressor cooler.

The heat from closed cooling cycle will be transfer through the heat exchangers to branch current of the main cooling water system.
The design of the closed cooling water pumps is 2x100%. This concept ensures that a failure of one pump does not lead to a reduction in the rated output of the plant.
The closed cooling water cycle will be filled with demineralized water to prevent contamination of the individual heat exchangers. For corrosion protection usually corrosion inhibitors will be added

7.6 Water and waste water systems

The water has to be treated in different steps to reach the qualities required by the processes. The water supply is necessary for:

- Cooling water system (provided from pre-treated water)
- Service water system
- Fire fighting system
- Process water for FGD plant
- Demineralized water for water-steam-cycle
- Potable water system

The water treatment plants are common standard plants with proven components. Sufficient redundancies are considered to provide a reliable water supply. Therefore a reliable operation can be expected resulting from the selected technologies.

Water treatment systems

The water treatment covers the following plants:

- Raw water pre-treatment plant
- Demineralization plant
- Potable water treatment plant

Pre-treatment plant

The raw water arriving to the site shall pass a pre-treatment in order to reduce the suspended solids by flocculation and sedimentation. Furthermore, chemicals for hardness stabilization and prevention of fouling will be dosed into the raw water.

The water quality downstream the pre- treatment shall have a value of less than 10 ppm for TDS (Total Dissolved Solids). This downstream water quality will be sufficient to be used for the following purposes:

- Cooling water make-up
- FGD plant
- Service water
- Fire fighting
- Potable water
- Coal and ash handling
- Demineralization plant.

The sludge coming from the flocculation and sedimentation process has to be treated before being disposed.

Demineralization plant

Following the pre-treatment, the water stream for water/steam cycle make-up water will be further clarified in the demineralization plant. This plant is based on reverse osmosis plus mixed bed technology cation and anion exchangers, which is proven and worldwide applied technology.

Considering copper free operation, the demineralised water shall have following quality to be used in the Benson type once through steam generator, depending on the treatment methods, which are All Volatile treatment (AVT), used for start-ups and shut downs, or Oxygen treatment (OT), used during normal operation:

Table 7-2 Feed water quality for once-through steam generator

Parameter	Unit	Value (for once-through steam generator, copper free operation)	
Treatment method		AVT (all volatile treatment)	OT (oxygen treatment)
pH		9,2 – 9,5	8,4 – 9,0
O_2	µg/l	5 – 20	30 – 150
SiO_2	µg/l	< 5	< 5
Fe	µg/l	< 5	< 5
Na	µg/l	< 2	< 2
Cu	µg/l	0	0
Acid conductivity	µS/cm	< 0.1	< 0.1
conductivity (only with ammonia dosing)	µS/cm	4.3 – 8.5	0.7 – 2.8
DOC	mg/l	< 0.2	< 0.2

Potable water treatment plant

The potable water treatment is necessary for several potable water consumers and consists of an activated carbon filter, a carbonization filter and a disinfecting system - two sets of chlorine dioxide generator (with HCl & $NaClO_3$). The raw water for the potable water treatment plant will be taken from the filtered water tank (water treatment plant).

Fire fighting water system

Fire fighting water will be taken from the water tanks after filtration (at water treatment plant). Since the filtered water supply for other consumers will be extracted at a certain tank level, the remaining tank volume will cover 2 hours supply for firefighting water according to NFPA 850

Condensate polishing system

The system adopts external regenerative type high speed mixed bed polisher. A medium pressure condensate polishing system will be considered for this project.
Treating capability of 100% of condensate flow at normal and peak operating conditions must be guaranteed.

Waste water treatment

The waste water treatment system will consist of the following parts:

- industrial waste water treatment
- oily waste water treatment
- sewage treatment

Industrial waste water treatment
Waste water from different plant areas (e.g. process drains, waste water from condensate polishing system, cleaning water from RO and ion exchanger system will be treated in the industrial waste water treatment to meet the effluent limits as required by effluent standard. The treatment will be designed as neutralization, precipitation / flocculation and sedimentation process. The treated waste water will be transported to the reuse water basin for further reuse. Any sludge from the industrial waste water treatment plant will be disposed of externally by trucks.

Oily waste water treatment
Oily waste water treatment system will consist of different oil-water separators located where oil spills are mostly likely to occur (e.g. steam turbine building, transformer area, fuel oil tank area). The treated water will be discharged to reuse water basin. The collected oil will be properly disposed.

Sewage treatment
The sanitary sewage water will be collected by pipe at various trapping points and transported into the sewage treatment plant by gravity.
The sewage treatment plant will be based on a biological treatment with a denitrification and dephosphorization process in order to meet the effluents limits .
The plant will consist of an equalization tank, sewage water lift pumps, uniform sewage water treatment device, filter, air blowers, chlorine dioxide generator (electrolysis process) and control equipment.

Rain water and fire fighting water retention system
Rain/storm water will be collected and discharged via separate system. The rain / storm water will be collected in a rain water basin. In case of fire the fire fighting water will also collected in this basin. The basin size will be based on maximum precipitation data and the maximum fire fighting waste water amount. During normal operation the collected rain water will be evaporated. In case of fire the polluted or contaminated water has to be removed and to be disposed of externally.
Waste water from the coal storage area
Waste water from the coal storage area will only occur during the rainy season. The water will be collected in the coal drainage basin for evaporation.

7.7 Auxiliary systems
Compressed air system
The central compressed air station will be designed for 2x600 MW power plant units. Instrument air and service air will be fed together by n+1 air compressors (dry running oil free air compressors) providing compressed air for both, the instrument air and service air systems. Both systems will be interconnected.
After leaving the after coolers of the compressor, the compressed instrument air will be dried in n+1 adsorption air driers and then led into the 2 x 100% instrument air receivers via fine filters. The compressed service air will pass fine filters and will directly be led into 2 x 100% service air receivers.
The compressed air station will be housed in the air compressor room or building.

Fire protection and fighting system
Fire protection and fighting systems will comply with local and NFPA standards and will include the following subsystems and equipment:

- structural fire protection measures for different buildings and areas
- smoke and heat removal systems
- fire detection and alarm system
- fire water supply system including:
  - fire water main with indoor/outdoor hydrants
  - 1 x 100% electrically driven pump,
  - 1 x 100% diesel motor pump
  - 2 x 100% jockey pumps
  - hydro- pneumatic tank with compressors
- fire fighting equipment including:
  - stationary extinguishing system
    - automatic and manual spray water deluge system,
    - transformer spray water deluge system
    - foam-water extinguishing system
    - automatic water sprinkler system
    - inert gas system
  - mobile and portable fire extinguishing equipment
- fire water retention system
- temporary fire protection and fire fighting measures
- fire fighting trucks

7.8 Electrical System

Each generator is connected directly to the 150 kV substation bus through one unit generator transformer (GT) three phase 180 MVA. One unit auxiliary transformer (UAT) three phase 25 MVA, are provided for each generating unit
One unit start-up/stand-by transformer (SST Transformer) three phase 20 MVA, is also provided to feed the power for auxiliary equipment during start-up and shut-down of the power plant.
The primary winding of start-up/stand-by transformer (SST Transformer) is connected to the 150 kV switchyard, and the secondary winding 6,3 kV is connected to the 6 kV medium voltage switchgear (MV switchgear) common bus.
Two voltage system has been selected 6 kV, and 0,4 kV as supply power for unit and auxiliary equipment.
The unit and station auxiliary power which supplied from the SST transformer during the start-up of unit power plant, through the unit and common bus section of medium voltage switchgears (MV switchgear), power distribution transformers (PDC transformers), power distribution switchgears (PDC switchgears), and motor control centers(MCC's). And after power plant running, the unit and station auxiliary power will be handled by UAT transformer automatically.

Generator

The generator is designed indoor operation in non air-conditioned hall in a site with tropical climate, directly coupled to steam turbine as its prime mover, and operated for continuously rating at the steam turbine maximum output.

The generator will be supplied complete with all necessary auxiliary equipment to make a completely functional system and include the following:

- Complete excitation system
- Generator Auxiliary systems
- Turbine generator common lubricating oil system
- Generator stator housing
- Bearing pedestals or brackets
- Phase and Neutral terminal leadings with bushing current transformers
- Terminal enclosure
- Rotor and cooler withdrawal and insertion gear, all special tools and instruments
- All required instrumentation and controls

Generator Transformer (GT)

The generator transformers (GT) is three-phase, two-winding, 50Hz, single tank, oil-immersed, triple rated type with ONAN/ONAF/OFAF cooling, and the generator transformers suitable for outdoor operation at rated power in a coal fired steam power plant on a tropical site.

The generator transformers used in step-up service to connect a turbine generator to the 150 kV switchyard/ network. And the high voltage neutral is solidly grounded system. The surge arrester is furnished and mounted on separate structures for connection on the HV side of the transformer.

Inter Phase Bus Ducts (IPB)

One complete set of isolated phase bus duct (IPB) is provided for each generator unit. The type of isolated phase bus duct is indoor and outdoor service, metal enclosed bus duct system, three-phase, complete with tee-off and connections for the generator, generator transformer (GT), unit auxiliary transformer (UAT), start-up/stand-by transformer (SST), voltage transformer (PT), surge protection cubicles (SA), generator circuit breaker (GCB) and. Generator Neutral Grounding Cubicle including, grounding transformers, grounding resistor, protection equipment and accessories with necessary connections

The isolated phase bus duct (IPB) complete including all accessories and appurtenances required for completely functional system.

The rating of voltage and current of isolated phase bus duct (IPB) not less than 5 % above generator rated voltage and current. And for branches bus duct not less than next standard rating greater than 5 % above the maximum equipments requirement respectively, at rated frequency 50 Hz.

Unit Auxiliary Transformer (UAT)

The unit auxiliary transformers (UAT) is three-phase, two-winding, 50Hz, single tank, oil-immersed type, and the UAT transformers suitable for outdoor operation at rated power in a coal fired steam power plant on a tropical site.
The UAT transformers used in step-down service to connect a turbine generator to its unit auxiliary power system. And the low voltage neutral is grounded through resistance (resistance grounding system).
The transformer impedance will be selected to limit the available short circuit current within the 6 kV switchgear rating and also to minimize voltage drop during motor starting with standard tolerance at 65 ºC, and The angular displacement of transformer is a standard phase relationship vector group YNyn + d11.

Medium Voltage Switchgear

Medium voltage switchgear is 6 kV,50 Hz ac for the power plant auxiliaries and miscellaneous accessories equipment, power will be supplied from UAT transformer, and SST transformer during start-up of power plant. All switchgear breakers designed for indoor service, electrically operated circuit breaker, three-pole, single throw complying with the IEC standard, and suitable for operation in a coal fired power plant located in a tropical climate. The switchgear are consist of circuit breakers, buses, and accessories, mounted on metal frame, complete with all electrical connections, and completely enclosed within sheet meta housing.

DC System

The station dc system will be on unit basis and each system will consist of a separate battery, an associated battery charger and a separate distribution panel.
220 V dc Supply System will be derived from the separate distribution switchboards consisting of 2 x 100% duty batteries which should be supplied by 2 x 100% duty battery chargers with eight hours operation capabilities without disturbing of the trip coils reliability through dc Supply will be derived from the separate distribution switchboards. Separate dc systems (battery and chargers) are to be provided for each unit, unit common and BOP, individually, as described in the following set.

- One set for each Unit Auxiliary(220V)
- The Unit Common shall be included in the Unit DC system
- One set for BOP Auxiliary(220V)
- One set for 150 kV switchyard (110V)
- One set for 150 kV switchyard for SCADA and communication system (48V)

The 220 Volts system for power plant shall supply dc power to dc motors, uninterruptible power supply inverters, emergency dc lighting, control power to switchgear, relays, plant annunciates, etc. The dc distribution panels also supply dc power for uninterruptible power supplies; dc motors, emergency lighting, circuit breaker control, plant control & instrumentation and data logging. Power will be supplied to the equipment from two sources, battery charges and batteries.
The dc distribution is a compartmented, ventilated, indoor type, free standing metal enclosures. They will be sectionalized to contain buses and connections, wiring, circuit breakers, control circuit and devices and distribution panel as required.

Control and Relaying

To perform the functions of power plant, the center control room and switchyard control room are designed in the turbine building and switchyard area.

All important signals of electrical equipment are sent to the DCS, and all the signals will control and monitored in the control room through DCS, which completed with visual monitor, keyboards and mousses. .All required control, protective relays, and metering for the generator, excitation system, circuit breakers, generator, unit auxiliary and station transformers are provided in the control room

All required control, protective relays, and metering for the 150 kV equipment such as 150 kV Circuit breakers, 150 kV Disconnecting/earthing switch, 150 kV Outgoing line, are provided in the switchyard control room.

Uninterruptible Power Supply (UPS) System

An uninterruptible power supply(UPS) system is provided for supply the electric power to the plant control system, 220 V AC. The critical AC power supply will included a rectifier, blocking diodes, DC/AC inverter, AC bypass power supply, static load transfer switch, induced harmonic filter, accessories, and other devices necessary to furnish of UPS AC power.

Normally, power supply to the power supply units is fed from the low voltage power distribution center (PDC) through rectifier, inverter and load transfer switch to the PDC bus. If incoming of AC supply system or rectifier fails, the input the input to the inverter will transferred automatically, through the blocking diodes without interruption of DC bus. If the output of the inverter fails, the critical bus will transferred to essential power by bypass AC power supply (critical bus will fed from the regulated bypass AC power supply through load transfer switch). The load transfer switch, also transfer the critical bus by bypass AC power sources, If the current requirement of critical bus exceeds the capability of inverter.

One 25kVA minimum capacity, uninterruptible power supplies will be furnished for each generating unit, one 25kVA minimum capacity uninterruptible power supplies U for common loads and one 25kVA minimum capacity uninterruptible power supplies for 150kV Switchyard.

Unit Metering and Protection

The unit metering and protection equipment will be provided for :

- Generator protection
- Generator Transformer (GT) protection
- Unit Auxiliary Transformer (UAT) protection
- Unit Tariff Metering Instrumentation

The unit metering and protection panels are free standing enclosures. The construction of the panels is in accordance with IEC Standard and other international standard.

All equipment on the panels shall be arranged in a logical manner. Electrically and physically separate panels will be provided for the protection for two (2) units.

Protective relays will comply with the requirement of IEC standard, or better. They are of digital type. Generator protection, Generator Transformer Protection, Unit auxiliary Transformer Protection be functionally redundant.
The detailed design of the auxiliary power and digital tariff metering system in accordance with the requirements outlined. The transducers will be provided for current, voltage, power and other electrical signals for metering.
The measuring of the power generation will be done at the generator terminals and the power consumption of the unit auxiliary transformer. The net generation will be measured at the 150 kV winding of the generator transformer.
All panels of control, protective relays, and metering for the generator, excitation system, breakers, unit and station transformers are provided in control room.

Grounding and Lightning Protection System

The project includes a proper grounding and lightning protection system which suitable in covering the whole plant area. A stable ground grid provides for grounding of equipment and structures and maintaining the step and touch potentials within safe limits. The computer system, communication and instrumentation grounding system will be separately. Building steelwork and floor reinforcement, and every second steel column of the turbine, boiler structures and all other buildings will be connected directly to the ground grid. All electrical equipments metal outer casing must be ground reliably in power plant. An earth mat is laid and buried at a suitable dept in ground and has ground rod electrodes at suitable intervals. All ground rod shall be 19 – 20 mm diameter of stainless steel or cooper rod at least 2,5 meters long. Lightning Protection will be provided for the whole plant installation, including Stack, etc.

Emergency Power Supply System

An emergency power supply system is provided of 2(two) sets of quickly start diesel generator set unit. The diesel generator set will supply the power to the emergency power system. One section of 400 V emergency PDC will receive the power from the diesel generator set, and distribute the power to emergency MCC. If the normal power loss from the PDC, the diesel generator set unit will started within 15 seconds and run at 100% loads automatically. The diesel generator set unit and its control equipment is located in the Diesel Generator room. Normally, emergency MCC is supplied from the unit low voltage transformer. In emergency (i.e. loss of station and unit auxiliary transformer), the diesel generator set unit will be supplied power to the emergency MCC

Communication System

The paging system will be of-the six-channel type; utilizing handset stations, speakers, tone generator, and amplifiers interconnected with suitable cable and raceway.
One channel will be a common-talking paging circuit and the other channels will be common-talking party line circuits.
Voice paging will be accomplished from any handset through all speakers in the system with automatic speaker muting provided where required to prevent acoustic coupling between adjacent handset and speakers units. When the paging circuit is

used for communication, all speakers except those automatically muted will carry all sides of the conversation.
Party line conversation will be accomplished from any handset to any combination of handset in system, utilizing transmitter and receivers in the handsets and muting all speakers to the conversation. All speakers will be available for paging during the use of the party line circuits.
The plant telephone system will be capable of accepting or sending up to ten external calls up to 50 plant telephone stations. Only internal telephone cabling of this power plant will be provided.

Lighting System
A combination of high pressure sodium vapor, fluorescent, and incandescent fixtures are used for the turbine hall, boiler platforms and galleries as necessary. The illumination levels at the various locations are maintained as stipulated in internationally accepted codes.
The normal AC lighting system is designed for the plant in under normal start-up, shut-down, and continuous operation. The power supply for normal lighting of each building units, switchyard area, road and others is got feed supply from LV lighting transformer, through the lighting panels, which placed in the buildings respectively, while for outside lighting such as road, yard and others may be got from 400/230 V distribution board nearby.
In abnormal condition, the emergency lighting exits door, stairs, essential equipment is supplied from the standby diesel generator for maintenance and safety. Emergency lighting by incandescent luminaries also provided in hall, exits ways, which operated from 220 V dc station battery.
A suitable number of lighting panels are supplied and installed at the convenient locations throughout the Plant. In addition to the normal illumination scheme, an emergency AC and DC lighting scheme is provided.

SCADA System
The SCADA system consists of the following four main sections:
- Master station hardware
- Master station software
- Communication facilities
- Remote terminal units

Instrumentation and Control System Description
The instrumentation and control system for the power plant will be integrated use Microprocessor Based Distributed Control System (DCS).
The DCS will have the following features:
- High reliability and availability,
- Failsafe operation,
- Capability being upgraded and extended,
- Safe for personnel and equipment,
- Optimum number of displays,

- 2 (two) seconds maximum response time,
- 100 ms maximum for data update,
- 1 millisecond maximum for Sequence of Events time stamp.

Thru the DCS, the power plant will be:

- operated, supervised, monitored continuously and centrally from new Central Control Room (CCR) under all operating condition i.e. plant startup, normal operation, plant shutdown,
- operated, supervised, monitored safely, reliably, efficiently, economically, simply, comprehensive operation, easy maintenance.

The DCS will be designed with the following four hierarchical levels:

- **Drive level.** Control and protection for individual equipment such as control valves, dampers, pumps and fans will be operated under this level.
- **Sub-group level.** The operation and control of a small group of individual equipment (a loop) will be initiated and stopped from this hierarchical level.
- **Group level.** Several control system under sub-group level (cascade loops) with their associated controllers will be operated under this hierarchical level.
- **Unit level.** This is the highest level in the control system architectures which functions as Unit Master Control (UMC) to perform Boiler Follow, Turbine Follow, and Unit Coordination mode of operation with associated peripheral devices / systems.

For overview of the DCS see Illustrative Drawing **-** Control System Configuration.

Operator Stations

Operator Stations will capable to execute automatic printing and alarming in case of any event, Plant Overview (the whole plant and sub-systems), Control Group, Multi-window, Trending, Tuning (manual and auto), Graphics, Logic & Calculations, Customize Functions, etc.

Supervision Stations

This station will functions same as operator station but intended for supervisor security access level and has additional features like to change controller parameters, program modifications and picture generation.

Operator Stations for Electrical Station

Function of the Operator Station is to monitor the status (like on, off, trip, etc) and measurements (like voltages, currents, frequency, power, transformer oil temperature, etc) of electrical equipment.

Engineering Work Station (EWS)

Engineering Work Station will capable to execute on-line reconfiguration, on-line change set-point, simulation.

External System Gateway
An external system gateway will be configured with subsystem to integrate third party foreign devices, such as Programmable Logic Controllers (PLC's) or Personnel Computer (PC) based package equipment, SCADA system and other smart devices.

Online diagnostics
The following self diagnostic facilities will be included as a minimum:
– System monitoring software, to detect hardware or software system lock-up / failure such as communication faults, processor faults, printer failure, etc.
– Detection of failure of any component, down to I/O level.
– Detection of an error on a unit of distributed control system will cause that unit's functions to automatically transfer to a backup distributed control unit.
– The DCS diagnostics alarms will be logged and will alert the operator to any equipment or software malfunction irrespective of the display being viewed at the time.

Sequence of Events (SoE)
The following events will be recorded as a minimum:
– Maintenance and start-up overrides,
– Shutdown/trip events,
– Faults / diagnostics alarms.

Maintenance and Management System (MMS)
The function of the Maintenance and Management Station is to summarize and display all process variables and calculated data on customized graphic, to enable performance and efficiency calculations, to provide paperless documentation, and to provide Information Maintenance Management System.

Historian Data System
Historian Data System will capable to manage data and information like logging, archiving, filtering, sorting, etc.

Access Security Level
At least 5 (five) security levels of access will be provided by password to provide the followings:
– View only level – permits to view graphics only,
– Operator level - permits to view all kind of display, to acknowledge an alarm, to reset an alarm.
– Supervisor level – permits to alter sensitive process parameters, to monitor and manipulate all functions allowed at the operator level, to manipulate tuning of loop parameters and alarm set point.
– Engineer level – permits to alter system configuration including all of the above.
– Special function – to be advised during maintenance period.

Boiler Control System

The following continuous measurement will capable to be monitored from CCR:

- Content of O_2, CO, CO_2, SO_2, and NO_x gas in stack,
- Content of moisture (H2O) in stack,
- Dust or Opacity in stack.

Boiler Control System at least will have the following controls:

- Protective interlocks,
- Burner control,
- Master fuel trip,
- Furnace purge control,
- Coal-air ratio control,
- Primary and Secondary air flow control,
- Fast Cut Back (FCB) Control automatically selected,
- Run Back Control automatically selected in the event of loss of Forced Draft Fan (FDF), Induced Draft Fan (IDF), Boiler Feed Pump (BFP),
- Boiler shoot blowing control,
- Firing rate control.

Steam Turbine Generator Control System

Thru the operator station and turbine control and protection panel, the turbine control system will capable to execute the following functions:

- Stably load control at the various loads and load changes,
- Interface with Controller Station and other foreign equipment,
- Manually speed control/adjustment (increase and decrease),
- Input set points.

Balance of Plant Control System

Balance of Plant Control System will include the followings:

- Coal Handling Control System,
- Ash Handling Control System,
- Water Treatment Control System,
- Waste Water Treatment Control System,
- Instrument and Utility Air Control System,
- Circulating Cooling Water Control System,
- Fuel Receiving and Storage Control Station,
- Intake Water Control System,
- Chemical Injection Control System.

The power plant also will be equipped with the following systems:

- Fire Alarm and Fire Extinguishing System,
- Close Circuit Television (CCTV) System,
- Emergency Shutdown System.

8 ENVIRONMENTAL CONSIDERATION

As mandated in Constitution 1945 and Act No.32 of 2009 on environment protection and management, the construction of any plant must be within the framework of sustainable development that takes into account the carrying capacity and environmental carrying capacity in each stage of development. Accordingly, economic growth through adding new energy sources must not degrade the quality of the surrounding environment so that the conservasion of habitats and living diversity is maintained.

Changes in land use

Land is a natural resource that can be used for various activities. Land consists of physical and biological environment associated with the carrying capacity of the livelihood and welfare of human life. Physical environment include topography, climate, soil, and water. It should be noted that the change in land use should be based on strategic environmental assessment and in accordance with spatial planning in the area.

Air and noise pollution

It should be noted that the power plant will impact air quality, especially during construction and operation. Transportation of building materials for construction and the construction itself would affect air quality and produce more noise at the project site. When the plant operates, various pollutants will be released such as dust, NOx and SOx. Emitted flue gas should be treated with appropriate technologies such as electrostatic precipitation and flue gas desulfurization, so that the air quality meets the ministerial decision No.13/1995 by the Minister of Environment and Governmental regulation No.41/1997. Another aspect to consider is that the height of the stack is calculated taking into account the wind rose, the distance to the community and the air-pollutant loads discharged into the atmosphere. In the operation phase, noise level will also increase due to the operation of plant equipment, so engineering efforts are needed to attenuate it. The air pollutants will adversely affect the health of local communities, and the discharge of flue gas will increase emission of greenhouse gases (GHG) into the air.

Water pollution

To minimize contamination of the water body where wastewater form the plant is discharged to, the wastewater must meet effluent quality standards in accordance with the Regulation No.8 issued in 2009 by the Minister of Environment, concerning wastewater quality for business and/ or activities of thermal power generators. Potential water pollution may come from:

Cooling water
The closed cooling method using cooling towers is planned for this power plant where only a small amount of water as makeup will be taken. The impact of this activity to the aqueous environment of the river is negligible.

Chemical contaminated and domestic wastewater
Chemical contaminated wastewater that comes mainly from the water treatment plant and power block must be treated by a neutralization process then a coagulation process to meet the relevant quality standards. Domestic wastewater which normally is high in BOD, COD, biodegradable organic compounds shall also need treatment before discharge, by a biochemical process with biological microorganisms. A wastewater treatment plant shall be constructed for in-situ treatment of all kinds of wastewater generated in the course of plant operation.

Waste oil
Waste oil comes mostly from the oil storage and pump house and from the machines where lubricating oil is used. Waste oil in oily water collected to the wastewater treatment plant shall be separated using the flotation technique or with oil traps so that it will not be released to the environment. Good housekeeping shall be practiced to prevent oil spills, so oil is not wasted in vain.

Runoff from coal storage
A good storage system is required so that the amount of runoff water from coal storage can be controlled. This runoff is acidic and contains suspended materials, thereby potentially contaminating the aqueous environment.

Runoff from ash
Bottom ash from coal combustion shall remain and be processed in a solid form so that the waste is immobilized, or it can even be solidified. If the waste is subject to water runoff, the installation of a runoff treatment system will be needed, so that the waste can be removed from the liquid phase.

Social impact
This impact will potentially arise at the pre-construction, construction and during operation. Land acquisition activities can cause social unrest if not handled properly. This activity can be undertaken by direct negotiation with the land owners, and the price of land shall be mutually agreed between the project owner and land owners. Land will need to be acquired primarily for the access road to the project site and project site itself. To acquire land for the power plant, about less than 100 households may have to be relocated. Further evaluation on social impact of the new Power Plant project may be subject to the EIA study and its mitigation program. At the operation stage, potential social impact can arise if liquid wastes, solids and gas from the power plant are not handled properly which may adversely affect the public health that can lead to continued social unrest. Environment management and monitoring is part of efforts to mitigate possible impact of plant development to the environment. Mitigating measures that will be done include: • Application of clean technologies

for the power plant • Properly processing of all solid, liquid and gaseous wastes to be generated from plant operation. • Recycling as much as practical treated wastewater for plant uses so that less wastewater is discharged to the outside of the plant. • Creation of a green fence around the project site to minimize the dispersion of dust and reduce noise generated from the plant operation.

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penerbit itenas
Jl. PKH. Mustapha No.23, Bandung 40124
Telp. +62 22 7272215, Fax.: +62 22 7202892
e-mail: penerbit@itenas.ac.id

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