Indian NAGARJUNA 2X600MW Coal-fired Units

Training Materials for Boiler Equipment and Its Operation

CONTENT

Chapter 1 Overview of Boiler DG2028-/17.45-Ⅱ5

1.1 Boiler Technical Specifications

1.1.1 Boiler Type

Indian Nagarjuna 2X600MW coal-fired boiler is manufactured by Dongfang Boiler Group Co., Ltd, (Sichuan • China). It is all steel structural Π type drum boiler of entirely suspended structure with sub-critical natural circulation, front & back wall opposed firing, single reheat, single furnace balance draft, dry slagging and hypaethral placement. The reheat steam temperature is adjusted by gas damper, with the air preheater arranged inside boiler main pillars.

Boiler model: DG2028-/17.45- Ⅱ5 type. DG represents Dongfang Boiler Works; 2028 means the steam flow (with unit of t/h) under BMCR working conditions. 17.45 indicates the boiler steam pressure (with unit of MPa) of this boiler under rated working condition; Ⅱ5 refers to the design number.

Boiler main design parameters are shown in Table 2-1

Items	Unit	BMCR	ECR
SH steam flow	t/h	2028	1876
SH steam outlet pressure	MPa(a)	17.5	17.5
SH steam outlet temp	℃	541	541
RH steam flow	t/h	1717.1	1596.38
RH steam inlet/outlet pressure	MPa(a)	3.95/3.75	3.67/3.48
RH steam inlet/outlet temp	℃	332/541	325/541
Feedwater temp	℃	282	277

Note:

a In the pressure unit, "g" refers to the gauge pressure and "a" means the absolute pressure (the same in the following training material).

b "ECR" refers to the boiler rated evaporation capacity.

c The boiler maximum continuous rating (B-MCR) is corresponding to the turbine intake steam flux under VWO condition.

1.1.2 Boiler Thermodynamic Properties

Items	Unit	B-MCR	TRL	THA	70%TRL	50%TRL	30%BMCR
SH steam flow	t/h	2028	1899.1	1787.0	1294.8	861.3	553.8
SH steam outlet pressure	MPa	17.50	17.40	17.31	14.33	9.53	7.55
SH steam outlet temp	℃	541	541	541	541	541	518
RH steam flow	t/h	1717.3	1607.0	1525.4	1125.5	762.6	495.5
RH steam inlet pressure	MPa	4.08	3.82	3.64	2.70	1.84	1.17
RH steam outlet pressure	MPa	3.90	3.66	3.48	2.60	1.66	1.09
RH steam inlet/outlet temp	℃	330/541	323/541	318/541	309/541	317/541	280/487
Feedwater temp	℃	281	276	273	254	232	208
Preheater inlet air temp	℃	25	25	25	30	38	45
Hot air temp	℃	306	303	301	291	279	255
Economizer outlet flue gas temp	℃	375/358	372/355	404/394	351/342	376/381	316/272
Exhaust gas temp (Correction)	℃	127	126	124	120	115	105
Calculation of boiler thermal efficiency	%	93.50	93.53	93.60	93.46	92.24	92.01
Furnace radiant heat	KJ/kg	11443.7	11631.2	11809.6	12105.3	11949.8	12306.8
Furnace volumetric heat load	KW/m3	91.10	86.44	82.21	62.73	44.05	28.76
Furnace sectional heat load	KW/m2	4441.00	4213.72	4007.47	3057.79	2147.47	1402.13
Heat load of furnace effective	KW/m2	125.55	121.08	116.92	91.44	63.40	42.63

area							
Furnace outlet temp	℃	1093	1074	1056	987	897	797
Furnace excess air ratio	/	1.18	1.18	1.18	1.242	1.455	1.607
Calculation of fuel consumption	t/h	274.11	260.08	247.35	188.73	132.54	86.54
Total fuel consumption	t/h	277.43	263.24	250.35	191.02	134.97	88.13
SH primary attemperating water flux	t/h	19.50	21.69	16.49	54.94	66.07	51.93
SH secondry attemperating water flux	t/h	13.00	14.46	10.99	36.63	44.06	34.62
Flue gas proportion at RH side	X	0.329	0.363	0.409	0.453	0.403	0.311

1.1.3 Boiler Design Conditions

1) Coal: the design coal for Indian Nagarjuna 2X600MW coal-fired units is bituminous coal imported (from Indonesia, South Africa and Australia). The coal quality analytical data and ash components are shown in Table 2-2:

Table 2-2: Coal quality analytical data and ash components

Items	Symbols	Unit	Design coal	Check coal Ⅰ	Check coal Ⅱ
Fuel categories			bituminous coal	bituminous coal	bituminous coal
Inherent moisture		％	11.0	11.0	2.0
Gross calorific value (AR)	Qgr,ar	Kal/Kg	5900	5350	6250
Hardgrove grindability index	HGI	/	47	45	52
Coal fineness	R90	％	18	18	18
Proximate analysis					
Total moisture (AR)	Mar	％	15.5	15.5	10

Items	Symbols	Unit	Design coal	Check coal Ⅰ	Check coal Ⅱ
Ash (AR)	Aar	%	4.23	5.49	13.56
Volatile content as dry ash-free basis	Vdaf	%	47.5	47.30	30.67
Fixed carbon (ADB)	Cad	%	44.1		
Ultimate analysis					
Carbon content as received basis	Car	%	61.01	57.36	64.52
Hydrogen content as received basis	Har	%	4.42	4.13	4.01
Oxygen content as received basis	Oar	%	12.76	15.56	5.42
Nitrogen content as received basis	Nar	%	1.28	1.07	1.84
Sulphur content as received basis	Sar	%	0.80	0.89	0.65
Ash fusion characteristics					
Deformation temperature	DT	℃	1235	1250	1300
Softening temperature	ST	℃	1305	1500	1300
Fluid temperature	FT	℃	1360		1300
Ash analysis					
Silica	SiO_2	%	45.17	42.86	48.50
Aluminum oxide	Al_2O_3	%	24.21	16.92	29.43
Ferric oxide	Fe_2O_3	%	9.52	9.86	3.89
Titanium oxide	TiO_2	%	0.85	1.35	1.74
Calcium oxide	CaO	%	6.30	8.12	10.18
Magnesium Oxide	MgO	%	3.29	3.30	2.16
Potassium oxide	K_2O	%	1.46	0.68	0.51
Sodium oxide	Na_2O	%	1.84	3.32	0.19
Sulfur trioxide	SO_3	%	6.52	12.96	2.74
Phosphorus pentoxide	P_2Q_5	%	0.69	0.46	1.70

2) Proximate analysis of ignition fuel and help fuel compositions:

Fuel type: light diesel oil

Dynamic viscosity (at 40℃):	2.5~15.7mm^2/s
Close-flash point:	66℃
Mechanical impurity (weight):	0.10%
Sulphur content (weight):	1.8%
Moisture (volume):	0.25%
Ash (volume):	0.02%
Residual carbon (weight):	≤1.5%
Specific gravity:	0.85(at 15℃)
Gross calorific value ($Q_{gt,ar}$)	10000kcal/kg

Fuel type:	heavy oil
Dynamic viscosity (at 50℃):	180~370mm^2/s
Close-flash point:	66℃
Mechanical impurity (weight:	0.25%
Sulphur content (weight):	4.5%
MAX moisture (volume):	1.0%
Ash (volume):	0.1%
Residual carbon (weight):	≤1.5%
Specific gravity:	0.95(50℃时)
Gross calorific value ($Q_{gt,ar}$)	10000kcal/kg
Condensing point:	50

3) Boiler feedwater and steam quality

Quality standards for boiler feedwater

The feedwater flow: during normal operation (2.5% of B-MCR) 50.7t/h

During startup or accident (6% of B-MCR) 121.7 t/h

Preperation methods for feedwater: primary demineralization with mixed bed system

Boiler normal blowdown rate: ≤1%B-MCR

Quality standards for boiler feedwater (indexes for normal operation)

Total hardness:	~0μmol/l
Dissolved oxygen:	≤7 μg/l
Iron:	≤15μg/l
Copper:	≤5μg/l
Silica:	≤15μg/l

Oil:	~0mg/l
PH value:	9.0~9.6
Hydrogen electric conductivity (25℃):	≤0.2μS/cm
Steam quality requirements	
Sodium:	≤5μg/kg
Silica:	≤20μg/kg
Hydrogen electric conductivity (25℃)	≤0.3μS/cm
Iron	≤15μg/kg
Copper	≤3μg/kg

1.2 Brief Introduction of Boiler

1.2.1 General Layout of the Boiler

The general layout of the boiler is shown in Figure 2-1.

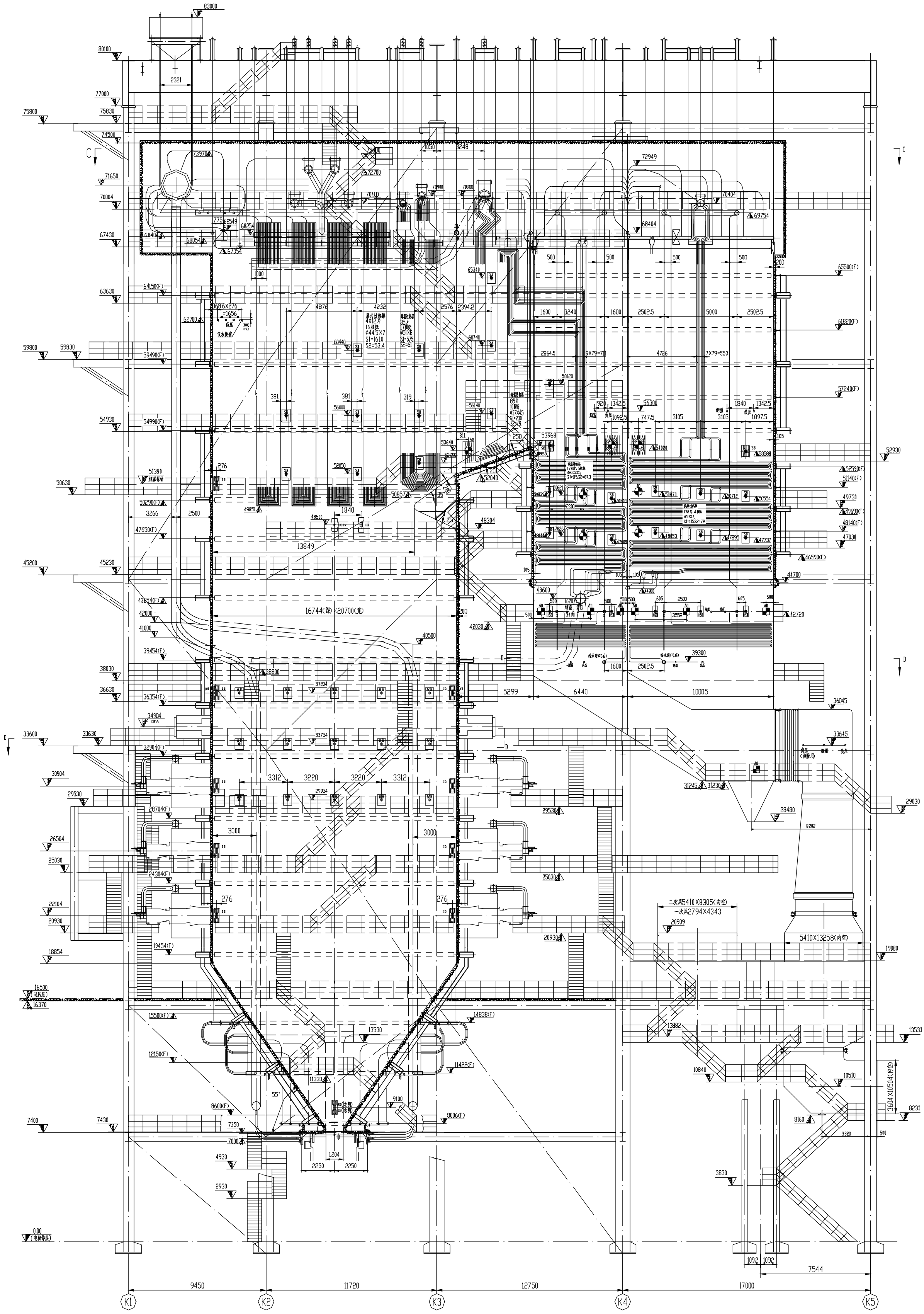


Figure 2-1 General layout of boiler

1.3 Boiler Technical Performance

1.3.1 Load Characteristics

Boilers are with basic load and have the capacity of regulating peak-load. When use design coal, the minimum loads for stable combustion without relying on oil support shall not exceeding 35% BMCR.

Continuous change rate of boiler load shall meet the following requirements:

When at 70% ~ 100% BMCR, it shall not be less than 5% BMCR per minute;

When at 50% ~ 70% BMCR, it shall not be less than 3% BMCR per minute;

When below 50% BMCR, it shall not be less than 2% BMCR per minute;

The permitted step variable load is 5% BMCR when load is below 50% BMCR and 10% BMCR when load is above 50% BMCR.

When a single air preheater is running, boilers can operate continuously and the boiler load can reach 60% B-MCR.

1.3.2 Operating Conditions

Operating modes: the boiler can not only operate in a mode of constant pressure-sliding pressure-constant pressure, but also in a mode of constant pressure. The boiler can fully meet the operating mode of steam turbine to operate in the above two modes.

Milling system: to adopt positive pressure direct blowing pulverizer of medium-speed primary air fans and to arrange 6 medium speed mills. When use design coal at BMCR conditions, there shall have five operating mills and one standby mill. Pulverized coal fineness shall be 16%, i.e., R90 = 16%.

Feed-water system: the feed-water system is designed as a unit. Two steam feed pumps with 50% BMCR capacity and one electrical governing feedwater pump with 30% BMCR capacity shall be arranged to the unit. The two steam feed pumps are to be used for normal operation and the standby electric governing feedwater pump is to be used for startup. Three high-pressure heaters shall adopt large bypass system, and the bypass capacity of the feedwater console shall be 30% BMCR. The feed-water system will also provide attemperating water for RH attemperator, SH attemperator and bypass system.

Bypass system: the unit is arranged with turbine bypass system, permitting the main steam to pass from high-pressure bypass to boiler reheater through cold reheated steam pipe, and permitting the reheater outlet steam to flow to air-cooled condenser through low-pressure bypass. The capacity is preset as per 35% BMCR.

Boiler ignition way: high-energy electric spark- light oil - pulverized coal

Deslagging way: continuous dry slagging. Each boiler adopts a submerged scraper ash conveyor. The ash storage volume of the boiler dry bottom hopper shall at least be able to store the slagging volume discharged during 4 hours at B-MCR condition.

Ventilation system: balanced draft.

The heating way for air preheater's inlet air: air heater.

When the boiler has been put into operation for one year, the annual utilization hours shall not be less than 6000, and the annual average running hours shall not be less than 7600.

Under both rated superheated steam temperature (50%~100% BMCR) and rated reheated steam temperature (60%~100%BMCR) operation, the rated temperatures at SH and RH outlet shall be kept, with ±5℃ temperature difference permitted.

In the regenerative system, if all primary or third high-pressure heaters are out of operation, the boiler evaporation capacity can still make the turbine-generator unit reach the nominal output with no heating surface overheated.

The designed pressure bearing capacity of boiler furnace shall not be less than ± 5.8kPa, and the instantaneous bearing pressure of the furnace shall not be less than ± 8.7kPa. When an abrupt flameout happened to the furnace or all the FD fans tripped and ID fans encountered the maximum instantaneous draft, the furnace and pressure parts will not suffer from a permanent deformation.

1.3.3 Boiler Steam, Water, Flue Gas and Air Resistance

The resistance for design coal at BMCR condition:

Superheated steam resistance	1.21MPa
Reheated steam resistance	0.17MPa
Economizer resistance （ including static differential pressure）	0.34MPa
Flue gas resistance of boiler proper(from furnace outlet to preheater inlet)	1112Pa
Primary air resistance of burners	1100Pa
Secondary air resistance of burners	1200Pa
Primary air resistance of air preheaters	199Pa
Secondary air resistance of air preheaters	797Pa
Gas-side resistance of air preheaters	947Pa

1.3.4 Boiler Efficiency

Under design coal, rated load, rated steam/water parameters, pulverized coal fineness of 16%(R90=16%) and ambient temperature of 20℃, the guaranteed thermal efficiency of the boiler shall be 92.57% (calculated according to net calorific value).

1.3.5 Boiler Thermodynamic Properties

Boiler performance calculations (design coal)

Item		Load / Unit	Constant pressure operation		
			BMCR	TRL	THA
Boiler parameters	Superheated steam flow	t/h	2028	1899.1	1787.0
	Superheated steam outlet pressure	MPa(a)	17.50	17.40	17.31
	Superheated steam outlet temp	℃	541	541	541
	Reheated steam flow	t/h	1717.3	1607.0	1525.4
	Reheated steam inlet/outlet pressure	MPa(a)	4.08/3.90	3.82/3.66	3.64/3.48
	Reheated steam inlet/outlet temp	℃	330/541	323/541	318/541
	Feedwater temp	℃	280.6	276.1	273
Drum operating pressure		MPa(a)	18.97	18.71	18.49
SH primary attemperating water flux		t/h	19.21	18.23	16.70
SH secondary attemperating water flux		t/h	12.81	12.15	11.14
Furnace volumetric heat load		KW/m^3	86.6	82.2	78.2
Furnace sectional heat load		KW/m^2	4435.4	4208.3	4002.4
Total fuel consumption		t/h	277.39	263.10	250.31
Calculation of fuel consumption		t/h	274.06	259.94	247.30
Calculation of boiler efficiency		%	93.25	93.30	93.33
Furnace outlet excess air ratio		/	1.18	1.18	1.18
Primary air temp at air preheater inlet		℃	20	20	20
Secondary air temp at air preheater inlet		℃	20	20	20

Item		Load / Unit	Constant pressure operation		
			BMCR	TRL	THA
Primary air temp at air preheater outlet		℃	317	316	316
Secondary air temp at air preheater outlet		℃	330	328	327
Flue gas temp	Flue gas temp at furnace outlet(at the rear side of finishing SH)	℃	977	963	950
	Platen SH outlet	℃	1093	1074	1056
	Finishing SH oulet	℃	977	963	950
	High temperature RH outlet	℃	818	809	801
	Low temperature RH outlet	℃	399	395	393
	Low temperature SH outlet	℃	409	406	404
	Economizer outlet(at convection SH/RH side)	℃	375/359	372/356	368/354
	Air preheater inlet	℃	368	364	361
	Air preheater outlet (before/after correction)	℃	133/128	132/127	132/126
Flue gas proportion at RH side		%	33.2	37.0	40.8
Medium Temp	Economizer outlet	℃	297	293	290
	Low temperature SH outlet	℃	391	389	387
	Platen SH outlet	℃	476	477	478
	Finishing SH oulet	℃	541	541	541
	Low temperature RH outlet	℃	433	435	438
	High temperature RH outlet	℃	541	541	541

1.4 Boiler Start-up Time

The time for boiler to be ignited and the unit to reach full load shall match the time requirement for steam turbine and shall meet the following requirements during normal startup:

Cold state startup	6 ~ 8 hours
Warm state startup	3 ~ 4 hours
Thermal state startup	1.5 ~ 2 hours
Extremely thermal state startup	<1.5 hours

1.5 Boiler Service Life

The boiler's main pressure parts shall have a service life of not less than 30 years. During the service life of 30 years, the permissible start/stop count shall not be less than the following values:

Cold start (for downtime more than 72 hours)	200
Warm start (for downtime from 10 to 72 hours)	2000
Thermal state startup (for downtime less than 10 hours)	3,000
Extremely thermal state startup (for downtime less than 2 hours)	500
Mutation load (10% TRL)	12000

Boiler drum and its main pressure parts shall have a sufficient safety margin during the designed service life of 30 years. The accumulated life expenditure shall not exceed 75% of its total lifetime.

Chapter 2 The Chief System and Basic Structure of Boilers

2.1 Water/Steam Flow

Boiler feedwater will be led in two ways from the boiler's right side respectively to the economizer inlet header at both RH side and SH sides. The feedwater will pass through economizer coil pipe, economizer hanger pipe inlet header, economizer hanger pipe and economizer hanger pipe outlet header to be introduced to the drum by connecting pipes, and then will mix with boiler water. After that, the mixed water will flow to the water wall lower header through downcomer and drain connecting pipe. The water will then flow upwards via the heated water wall, generate steam and form steam-water mixture which will pass from the water wall upper header to boiler drum introduced by connecting pipes. The water and steam will be separated by the cyclone separator in the boiler drum. The separated water and feedwater will mix together and carry out recirculation after entering the furnace water wall. Meanwhile, the separated saturated steam will sequentially pass roof superheater, wall enclosure superheater, low temperature superheater, platen superheater and high temperature superheater, and will finally be led out by high temperature SH outlet pipe from the left and right sides.

About two intersections are designed in the whole superheater system, namely, about one intersection from low temperature SH outlet to platen SH inlet and one intersection from platen SH outlet to high temperature inlet. In this way, the influence of unevenness resulted from flue gas along the width of the boiler can be effectively reduced. As such, it helps to reduce thermal deviation among platens and among tubes.

Two-stage spray attemperation is adopted in the superheater system. The primary spray attemperators are arranged at the connecting pipe between low temperature SH outlet header and platen SH inlet header, while the secondary spray attemperators are arranged at the connecting pipe between platen SH outlet header and high temperature SH inlet header. Both the primary and secondary attemperation have been arranged two spray attemperators which will respectively spray attemperating water from the right side and left side. The primary attemperators are used for coarse adjustment and for protection of platen SH, while the secondary attemperators are used for fine adjustment of the superheated steam temperature

and for keeping the superheated steam outlet temperature at rated value.

The steam discharged by turbine HP cylinder will enter low temperature RH inlet header respectively from the right side and left side, flow to RH outlet header through low temperature RH and high temperature RH, and finally be introduced by high temperature RH outlet pipe to turbine IP cylinder respectively from the right and left side.

A direct connection of low temperature RH and high temperature RH without intermediate header can effectively reduce the resistance of RH system.

Two emergency spray attemperators of reheater arranged at low temperature RH inlet duct will spray attemperating water respectively from the right and left side. Emergency attemperators of reheater are to be used only under emergency conditions, disturbance conditions or other unstable conditions. Under normal conditions, the reheater steam temperature shall be adjusted by flue gas damper arranged at the back-end ductwork. For full load, the flue gas damper at SH side shall be fully opened, and the flue gas damper at RH side shall be partly opened. For gradually decreased load, the damper at SH side shall be gradually closed and the damper at RH side shall be gradually opened and be fully opened after the boiler reaches the minimum load.

2.2 Flue Gas and Air Flow

The flue gas generated after burning of pulverized coal in lower furnace will pass from lower furnace to upper furnace in the following sequence:

Low temperature RH→Economizer at LT RH side

Platen SH→Finishing SH→High temperature RH

Low temperature SH→Economizer at LT SH side

→Flue gas damper→Air preheater→Dust cleaner→Chimney.

The air will be introduced to two 3-compartment rotary air preheaters through air heater by two FD fans. The hot flue gas leaving the boiler will transfer its heat to the intake air. The heated primary air will mix with the bypass cold primary air, enter coal pulverizers and bring pulverized coal to the coal burner. The heated secondary air will enter the large air box of secondary air, and then enter furnace through the coal burner and OFA regulator.

2.3 Basic Structure

2.3.1 Feedwater and Economizer System

Feedwater pipelines are divided into two lines: one is the main feedwater pipeline arranged with one electric gate valve; the other is the start-up bypass arranged with two electric gate valves and one electric control valve. During start-up, in addition to the electrical governing feedwater pump, the bypass control valve can also be adjusted to achieve automatic feedwater control at low load.

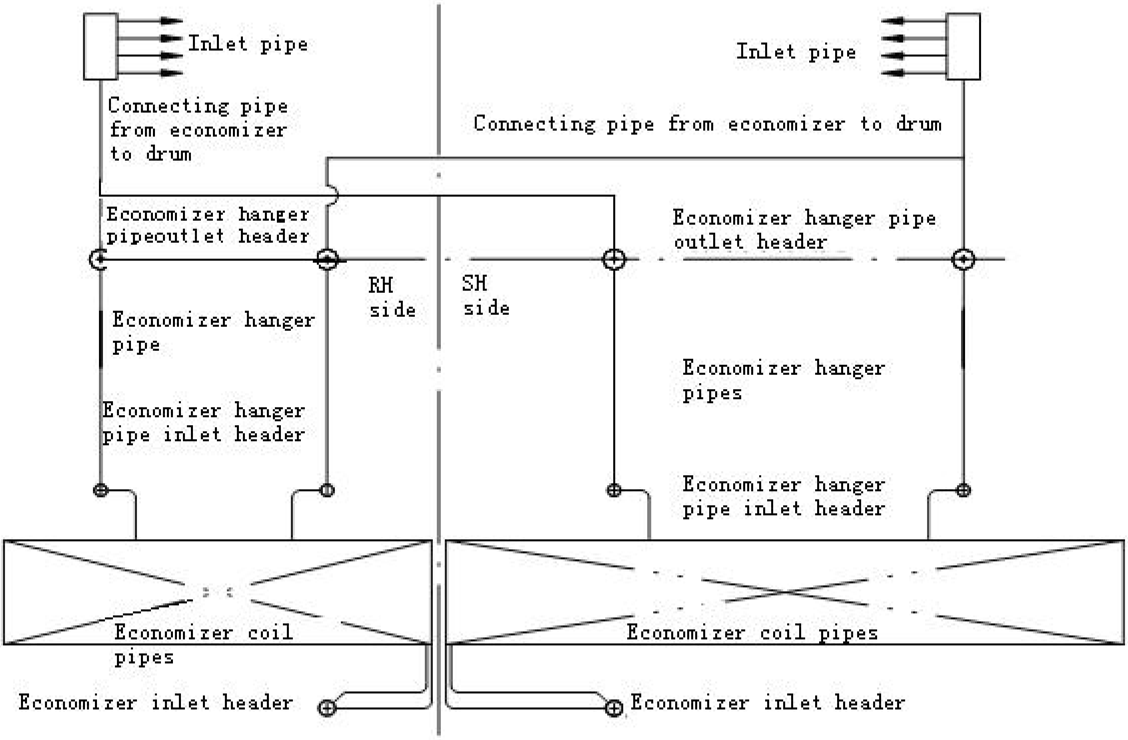
Boiler feedwater will flow respectively in two lines from feedwater pipe inlet (Φ355.6×30, WB36) to economizer inlet headers (Φ406.4×60, SA-106C) at RH and SH side. It will then flow to four(2 at RH side and 2 at SH side) economizer hanger pipe inlet headers (Φ219×30, SA-106C) through the economizer coil pipes at RH and SH side, flow to four(2 at RH side and 2 at SH side) economizer hanger pipe outlet headers (Φ323.9×40, SA-106C), then be led in the front of the furnace after passing to the two large connecting pipes(Φ406.4×40, SA-106C) at the right and left sides, and finally be introduced to boiler drum through the two distributing headers(Φ406.4 × 50, SA-106C) at the right and left sides by 16(8 at the left side and 8 at the right side) inlet pipes(Φ127×15, SA-106C).

Located in the gas duct of the rear vertical shaft and below low temperature RH and SH Economizer, the coil pipes (Φ51×6, SA-210C) have an in-line arrangement along the duct width. Economizer coil pipes at RH side are two pipes coiled together with counter-flow arrangement. The transverse pitch is 115(S1=115), the transverse row number is 178, the longitudinal pitch is 71.1(S2=71.1) and the longitudinal row number is 24. Economizer coil pipes at SH side are also two pipes coiled together with counter-flow arrangement. The transverse pitch is 147(S1=147), the transverse row number is 140, the longitudinal pitch is 71.1(S2=71.1) and the longitudinal row number is 24.

Economizer hanger pipes (RH side: Φ51×10, SA-210C; SH side: Φ57×11.5, SA-210C) are arranged in four rows along the rear duct depth. The horizontal heating surfaces of low temperature RH are hung by the economizer hanger pipes at RH side which are arranged in two rows along the furnace depth, with 89 pipes in each row. The transverse pitch is 230(S1=230) and the longitudinal pitch is 3240(S2=3240). The horizontal heating surfaces of low temperature SH are hung by the economizer hanger pipes at SH side which are arranged in two rows along the furnace depth, with 89 pipes in each row. The transverse pitch is 230(S1=230) and the longitudinal pitch is 5000 (S2=5000).

Wear plates are arranged in the vulnerable area of the first row of economizer coil pipes. In order to prevent the formation of flue gas corridor at economizer flue gas inlet, flue gas spoilers are arranged in the economizer coil pipe bundles and the surrounding enclosure walls. Since economizer inlet header and hanger pipe inlet header are located in the gas duct, wear plates are arranged in the headers to prevent soot particle abrasion.

Work flow of economizer:



The economizer span at RH side is 6440, and no anti-vibration device is arranged. The economizer span at SH side is 10005 and anti-vibration device is arranged in the middle of coil pipes to prevent vibration.

Economizer inlet header and coil pipes are hung under economizer hanger pipe inlet header by pipe clamps. Economizer hanger pipes are hung under economizer hanger pipe outlet header and the header climbing pole will transfer the load to the steel frame at the top of the boiler. Rooted in the girder of the economizer ash hopper, the anti-twist device of economizer inlet header will transfer the thrust borne by feedwater pipe to cold structure through the girder.

2.3.2 Drum

Drum inside diameter is 1800(Dn=1800), with wall thickness of 145, drum straight length of 24.733m, both ends of spherical heads, and a total length of about

26.983m. The material for drum body and spherical heads is 13MnNiMo54 (i.e. BHW35). They are suspended on roof girders by two U-climbing poles of Φ200 and are able to ensure a free thermal expansion of the steam drum. The material for the climbing poles is SA-675Gr.70. Drum centerline elevation is 71.65m, and the total weight of drum and internal equipment is about 210 tons.

Drum can reserve a certain amount of water to meet the instantaneous change in feedwater flow and to ensure an optimum degree of supercooling of the water entering the downcomer. Drum normal water level is 51mm above the drum centerline. Compared with the normal water level, high water-level alarm is +100 mm, and low water-level alarm is -100mm; high level trip is +200 mm and low level trip is -365mm. Drum water level measured by single chamber balancing vessel shall prevail and shall be the basis for water level adjustment and control.

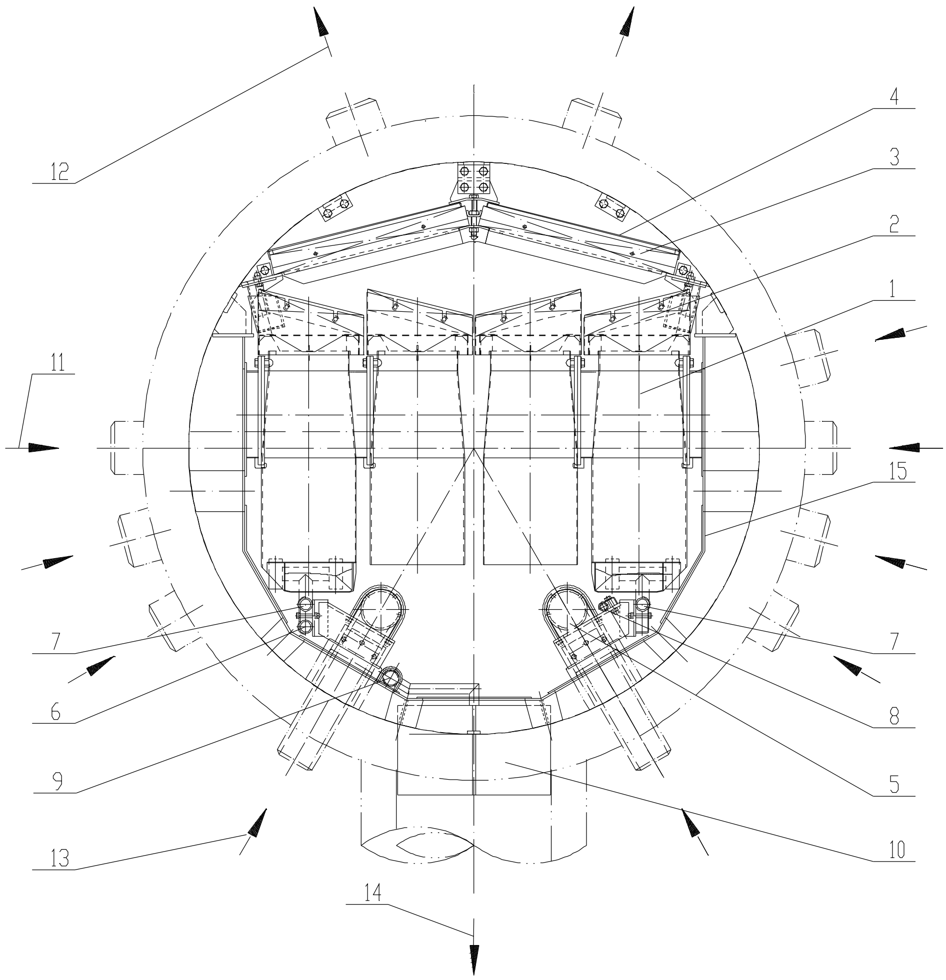
Drum is an important part of the natural circulation system in that steam-water separation is carried out in the drum. The primary separative elements of the drum internal equipment are 218 tangential cyclone separators designed and manufactured with mature technology. The steam from the top of cyclone separators will pass in sequence the cyclone separator top cap, louver separator, and homogeneous steam panel for further steam-water separation. The separated water will mix with feedwater and then carry out recirculation after entering the furnace water wall. Meanwhile, the separated saturated steam will enter roof superheater inlet header through saturated steam outlet pipe. The lower half of the drum adopts the inside jacket structure of steam-water mixture, or in other words, the steam-water mixture will flow from this inside jacket to tangential cyclone separators for primary separation, the feedwater pipe will introduce feedwater to the drum from the bottom of the drum, the jacket will separate feedwater and boiler water from the drum inner wall, the steam-water mixture in lower jacket is in a status of flow, and all these enable a consistent temperature between the drum upper wall and lower wall as far as possible.

The drum spherical heads are arranged with two sets of no-blind-zone double colored water level gauges, two sets of electrical contact water level gauges, three sets of single chamber balancing vessels and one set of full water balancing vessel. These equipment are used for thermal protection, feedwater adjustment and mechanical read of lower water level. The drum body is arranged with pressure signal connectors used for pressure alarm and combustion adjustment, etc. In addition, there are other accessories such as emergency drainage, continuous blow-down, air

exhaust, chemical feeding and pressure gauge. For the purpose of reducing fluctuations in drum water level, an almost equal steam generating rate of the front part and the rear part of the drum is designed. Meanwhile, corresponding water level equalizing pipes are arranged for water level gauge and balancing vessel pipe joints at water side in the drum, so as to make the shown water level coincide with the true water level. In order to achieve even dosing, blow-down and feedwater, communicating pipes for dosing, blowdown and feedwater are arranged along the drum length, with a certain number of openings on communicating pipes. Besides, in order to avoid stress fatigue resulted from temperature differences, the outlet pipes, chemical feed pipes and feedwater pipes at water side of water level gauge and balancing vessels are arranged with bushings.

Six spring safety valves are arranged in the drum to ensure safe operation of boilers.

Three drum guiding devices are arranged in the boiler top box. The first one is located at the symmetrical centerline of the boiler on its top, and the other two are located at the symmetrical centerline in its front, 11163 from the sides of the drum.

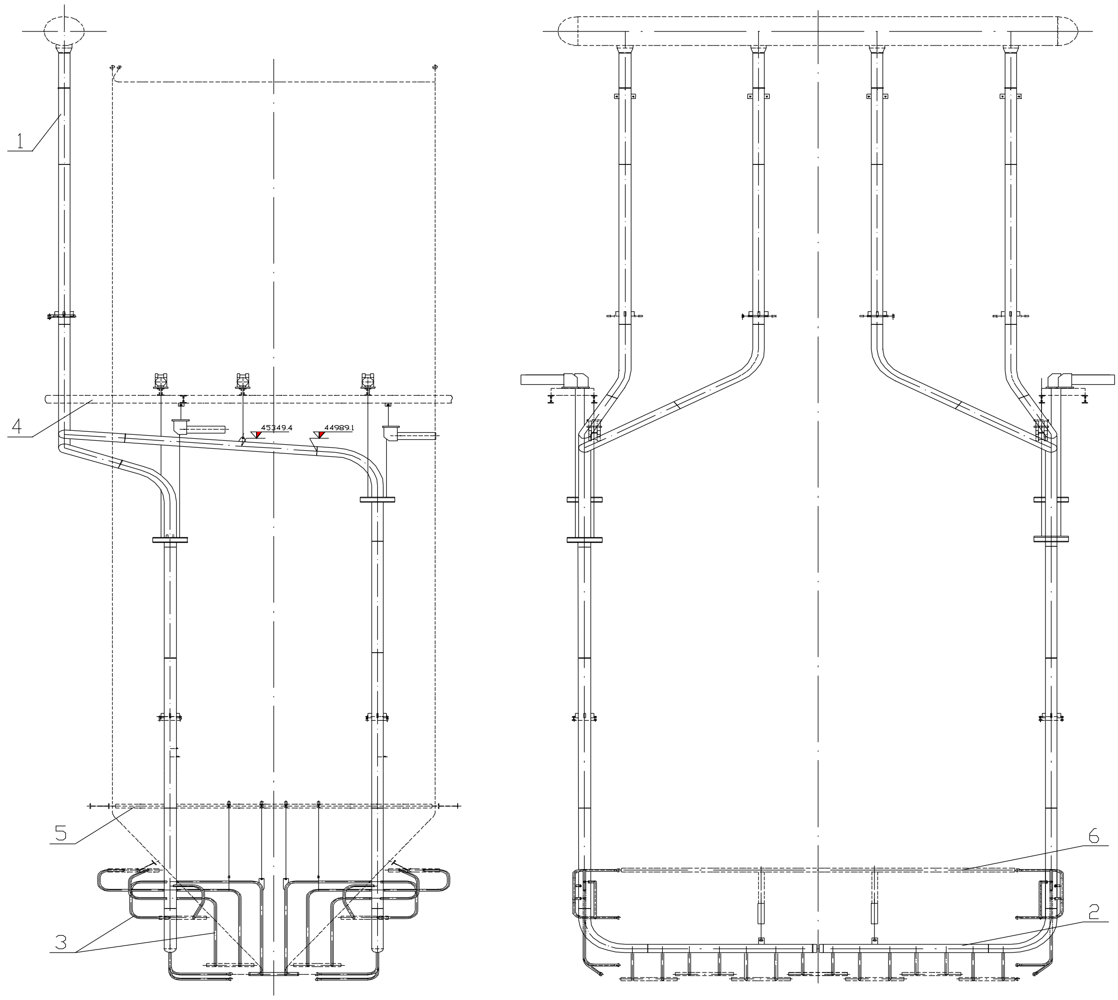


Layout of Drum Internals

1- Cyclone separator	2- Cyclone separator top cap	3- Louver separator
4- Homogeneous steam panel	5-Feedwater distribution pipe	6-Water level equalizing pipes for water gauge
7-Water level equalizing pipes for balancing vessels	8-Dosing pipe	9- Parallel pipe
10-Anti-rotation device	11- Steam-water mixture	12-Saturated steam
13-Feedwater	14-Boiler water	15-Steam-water mixture inside jacket

2.3.3 Downcomer System

Boiler downcomer system consists of 4 centralized downcomers(Φ609.6×60, SA-106C), 4 downcomer distributing mains(Φ609.6×65/80, SA-106C) and 56(14 per wall) drain connecting pipes(Φ141×16, SA-106C). One blank cap (Φ28×4, 20) is arranged in each centralized downcomer for nitrogen-filling. Economizer recirculation tube (Φ133×16, SA-106C) is also arranged in the rear downcomers at the right side of boiler.



Layout of Downcomer System and Hanging Diagram

1-Centralized downcomer	2-Downcomer distributing main	3-Drain connecting pipe
4-Frame girder	5-Rigid girder	6-Rigid girder

2.3.4 Furnace and Water Wall System

Furnace is a place in boiler where fuel will be burned, so it is also known as the combustion chamber. Furnace is an important part of boiler combustion equipment. Apart from transforming fuel chemical energy into thermal energy of combustion products, the furnace also undertakes the task of heat exchange. Therefore, the furnace shall be structured to ensure fuel burnout and make the furnace outlet flue gas cooled to a permissible temperature for safe operation of the convection heating surface behind the furnace.

Water walls are evaporating heating surfaces laid around the furnace and

consisted of many parallel pipes. They have the following main roles: to absorb the radiant heat from furnace medium-high temperature flame and flue gas; to vaporize the water inside water wall for saturated steam; to protect furnace walls by decreasing destructive influence of high temperature on furnace walls; to enhance heat transfer, reduce boiler heating area and save metal consumption; to effectively protect furnace walls from slagging; to suspend furnace walls.

2.3.5 Furnace Geometric Properties

Furnace geometric properties mainly refer to its width, depth, height and geometric shapes. These geometric properties are all related to the main thermodynamic properties of the furnace. Furnace geometric properties are one of the important factors for the furnace conformance to design requirements.

Around this boiler furnace are membrane water walls of all-welded type. Sufficient holes such as observation holes, thermal pickup holes, monitor holes for furnace pipe leakage, manholes and sootblowing holes are arranged in water walls. The furnace is of 20700mm width, 16744mm depth, 67.43m boiler roof pipe centerline elevation and 16895.7m^3 furnace volume. Furnace hopper is formed by tilting the front & rear wall at furnace bottom with an elevation of 18.854m inwards an angle of 55°. The arch nose of this boiler is located in the rear wall of 50.29m elevation, with height of 3736mm and depth of 2895mm. The roles of the arch nose are as follows: Firstly, to extend the flue gas flow, improve fill factor of flue gas and enhance the turbulence and mix of flue gas; secondly, to reduce furnace outlet heating surface erosion; thirdly, to add length of horizontal flue, which helps to the arrangement and operation of SH and RH.

2.3.6 Furnace Heat Load

The main thermal property of the furnace is the average heat hourly input to furnace by fuel，or referred to as furnace capacity.

According to the methods of calculating, the furnace heat load can be classified into the following types, and they all are the main thermodynamic parameters to which attention must be paid during boiler design and operation.

1) Furnace volumetric heat load

The heat input to unit furnace volume per unit time is referred to as furnace volumetric heat load. It is expressed by qv and the unit is kW/m^3 or MW/m^3.

2) Furnace cross-section heat load

The heat input to unit furnace cross-section per unit time is referred to as furnace cross-section heat load. It is expressed by qa and the unit is kW/m^2 or MW/m^2.

3) Burner zone wall heat load

Calculated according to unit furnace wall area in burner zone, the heat input to furnace per unit time is referred to as burner zone wall heat load. It is expressed by qr and the unit is kW/m^2 or MW/m^2.

4) Furnace radiant heating surface heat load

The heat absorbed by unit furnace radiant heating surface per unit time is referred to as furnace radiant heating surface heat load, and also as furnace wall heat flux density. It is expressed by qf and the unit is kW/m^2 or MW/m^2.

Design data for furnace and water wall of this boiler

Furnace section (furnace width × depth)	20700×16744m×mm
Furnace volume	16895.7m^3
Furnace volumetric heat load	87.26kW/m3
Furnace cross-section heat load	4.2537KW/m2
Furnace effective area heat load	104.38KW/m2
Furnace outlet flue gas temperature (at the rear side of finishing SH)	1027℃
Platen SH outlet flue gas temperature	1100℃

Note: 1) Furnace outlet cross-section is defined as the cross-section formed by the first row pipe centerline of the heating surface whose net distance between pipes along flue gas flow is averagely equal to or less than 457mm.

2) Furnace volume is defined as the volume from the upper height of the effective volume at the bottom of furnace hopper to furnace outlet cross-section.

3) Heat load shall be calculated according to the net input of furnace heat which is the product of the calculated coal consumption (i.e., the coal consumption allowing for losses in q4) corresponding to boiler load multiplies net calorific value of fuel.

4) Burner zone is selected as the furnace wall area surrounded by the vertical distance of the centerlines between the upper and lower pulverized coal injectors plus 3m.

2.3.7 Boiler Water Wall

Boiler water wall system consists of 28 (7 for each wall) water wall lower headers(Φ219×40, SA-106C), water wall tubes, 4 (each for the front & rear wall and two sidewalls) water wall upper headers (Φ273×55, SA-106C), 3 (each for two sidewalls and the rear wall) horizontal flue upper headers (Φ273 × 50, SA-106C) and 84 (22 for the front wall, 18 for each sidewall, 6 for the rear wall, 10 for each sidewall at horizontal flue, and 10 for the rear wall at horizontal flue) steam/water outlet

pipes(Φ168×18, SA-106C). To improve the strength of water wall lower headers, no through holes will be opened in the water wall lower headers, instead, orifices (dr=32mm) will be adopted.

Around the furnace are membrane water walls of all-welded type. Sufficient holes such as observation holes, thermal pickup holes, monitor holes for furnace pipe leakage, manholes and sootblowing holes are arranged in water walls. The furnace is of 20700mm width, 16744mm depth. Waterwall tubes are bare pipes of Φ66.7 × 8, SA-210C. In order to ensure a safe and reliable water circulation, internally ribbed tubes of Φ66.7 × 8, SA-210C are adopted in high heat load area in the furnace to prevent film boiling. By doing so, a larger safety margin of DNB can be ensured to avoid any deteriorated heat transfer under any working conditions and to avoid flow stagnation, return flow and film boiling, etc. The water wall tube pitch is 92. There are 812 waterwall tubes in all, with 224 waterwall tubes arranged respectively in the front & rear walls along the furnace width and 182 waterwall tubes arranged respectively in the two sidewalls along the furnace depth. Randomly select one from five waterwall tubes in the rear wall of the arch nose area behind the furnace to form furnace outlet hanger tube bundles. There are 44 hanger tubes in total, with specification of Φ82.5 × 11, material of 15CrMoG and transverse pitch of 460. These hanger tubes are connected with waterwall tubes in the rear wall respectively by using lugs and hangers in the upper and lower inflexion of the arch nose.

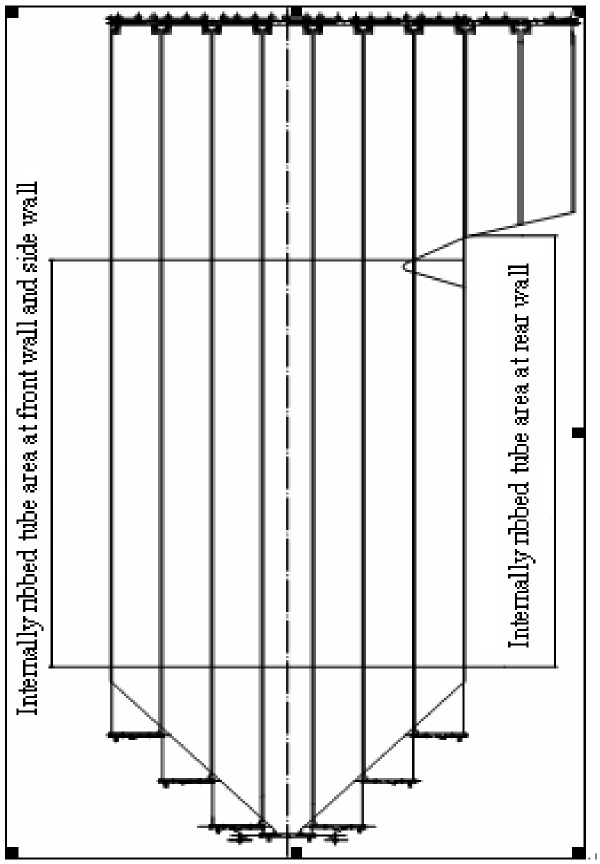
The horizontal flue is of 20700mm width and 5299mm depth, and its waterwall tubes are bare pipes of Φ66.7 × 7, SA-210C. The bottom of the horizontal flue is formed by bending the 180 waterewall tubes (remainders after selection one from five) in the rear wall towards horizontal flue, with pitch of 88, 115, 131.9. The water wall at horizontal flue side is formed by bending the tubes at both sides of the bottom of horizontal flue towards horizontal flue sidewall, with 40 waterwall tubes at each side and with pitch of 100.5 and 131.9. The horizontal flue outlet bundle is formed by bending backwards and upwards the tubes in the middle of the bottom of horizontal flue, with 100 tubes in 44 rows, and with a transverse pitch of 460(S1 = 460) and a longitudinal pitch of 100.7/151.3(S2=100.7/151.3).

According to the furnace heat load distribution and geometric shapes, the furnace water wall is divided into 30(7 for the front wall, 7 for the rear wall, and 8 for each sidewalls) flow circuits. An individual drainage pipeline is arranged in each flow circuit and be opened only at atmospheric pressure after boiler shutdown.

To speed up the boiler startup, water wall lower headers are arranged with steam

heating devices adjacent to furnace, including steam heating distribution pipes, high pressure stop valves, distribution boxes and pipes connected to water wall lower headers.

Figure 3-2 Layout of internally ribbed tubes at water wall

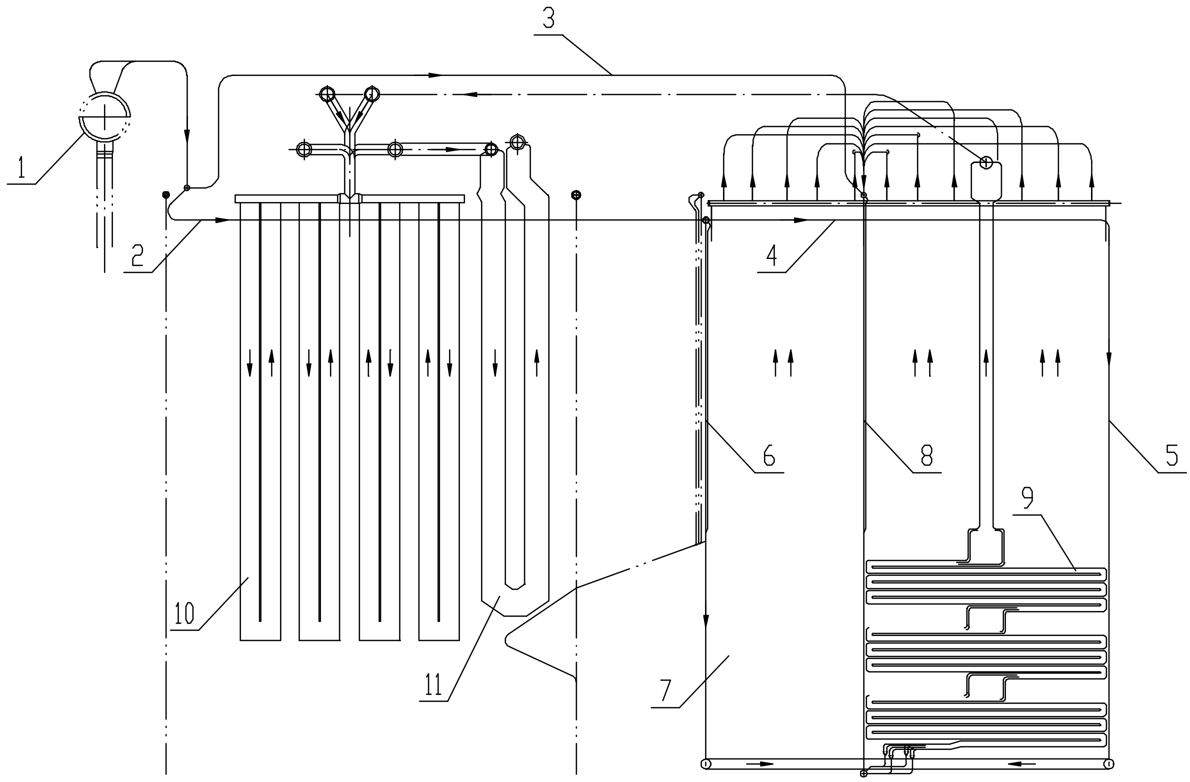


Layout scope of front & side wall internally ribbed tubes on water wall: 19954mm-50790mm(elevation)

Layout scope of rear wall internally ribbed tube on water wall: 19954mm-52150mm(elevation)

Superheater System

Superheater system consists of roof SH, wall enclosure SH, low temperature SH, platen SH and high temperature SH.



1-Drum	2-Roof SH	3-Steam bypass pipe	4-Top wall enclosure
5-Rear wall enclosure	6- Front wall enclosure	7-Side wall enclosure	8-Middle baffle wall
9-Low temperature SH	10- Platen SH	11-High temperature SH	

Figure 3-4 Flow chart of superheated steam

1) Roof SH and wall enclosure SH

The saturated steam from the top of the drum will enter roof inlet header(Φ219×35, SA-106C) through 20 steam outlet pipes (Φ168×18, SA-106C). In order to reduce steam resistance, the steam in roof inlet header will be led out from two ways: one way is to be directly led to middle partition wall upper header in rear vertical shaft(Φ273×50 , SA-106C) through 4 steam bypass pipes (Φ168×18, SA-106C), and the other way is to be introduced to roof SH. Consisted of 180 pipes of Φ63.5×6.5, 15 CrMoG, the roof SH is arranged with prepared holes specially used for erecting temporary lift and scaffolding for furnace internal overhaul. After heated by roof SH, the steam will enter roof outlet header(Φ273×50, SA-106C) and then will enter lower circular header in rear vertical shaft(Φ406.4×60, SA-106C) in two ways respectively from front wall enclosure in rear vertical shaft(Φ44.5×5.5, SA-210C, a total of 181) and top wall enclosure and rear wall enclosure in rear vertical shaft(Φ44.5×5.5, SA-210C, a total of 180). The steam from the two ways will converge to flow upwards

to sidewall upper header in rear vertical shaft (Φ219×40, SA-106C, 6 for each side) through sidewalls in the rear shaft (Φ63.5×8, SA-210C, 142 for each side) and then enter middle partition wall header in the rear shaft (Φ273×50, SA-106C) through 24 wall enclosure connecting pipes (Φ168×18, SA-106C). The steam from the two ways will converge to flow downwards to convection SH inlet header (Φ273×45, 12 Cr1MoVG) through middle partition wall in the rear shaft (Φ63.5×8, SA-210C, a total of 179).

2) Low-temperature superheater

Located in the BP rear gas duct, low temperature superheater can be classified into horizontal and vertical sections. The horizontal section has an in-line counterflow arrangement, with three pipe groups. A certain maintenance interval is kept between pipe groups. The first pipe group in horizontal section are pipes of Φ57 × 7, SA-210C, with a transverse pitch of 115(S1=115) and a longitudinal pitch of 79(S2=79). There are 4 clamp pipes and 178 platens. The second and third pipe groups in horizontal section are pipes of Φ57×7, 15 CrMoG, with a transverse pitch of 115(S1=115) and a longitudinal pitch of 79(S2=79). There are 4 clamp pipes and 178 platens. When pipes enter the vertical section from horizontal section, every two platens will be integrated into one platen. The vertical outlet pipe section are pipes of Φ57×7, 12 Cr1MoVG, with a transverse pitch of 230(S1=230) and a longitudinal pitch of 79(S2=79). There are 8 clamp pipes and 89 platens.

The pipe groups at horizontal section of convection SH are suspended under the girder by economizer hanger pipes. The support pieces for the pipe groups in horizontal section are of ZG1Cr18Ni9Ti. The vertical outlet pipe sections are suspended under the girder by high top plate construction.

3) Platen SH

Superheated steam will pass from convection SH outlet header (Φ609.6×65,12 Cr1MoVG) to the front and rear platen SH inlet distributing header(Φ609.6 × 65,12 Cr1MoVG) through the right & left SH primary attemperator inlet connecting pipes(Φ609.6×55, 12 Cr1MoVG), the right & left SH primary attemperaotrs (Φ609.6×60, 12 Cr1MoVG) and the right & left SH primary attemperator outlet connecting pipes (Φ609.6×55, 12 Cr1MoVG). The superheated steam will then be introduced to 4(2 at the right side and 2 at the left side) platen SH inlet headers(Φ323.9×40 , 12Cr1MoVG) by 4(2 at the right side and 2 at the left side) platen SH inlet connecting pipes(Φ323.9 × 30,12 Cr1MoVG). And it will enter 4(2 at the right side and 2 at the left side) platen SH outlet headers (Φ368 × 60,12

Cr1MoVG) after heated by platen SH and then be introduced to the front and rear platen SH outlet influx headers(Φ609.6 × 75,12 Cr1MoVG) respectively by 4(2 at the right side and 2 at the left side) platen SH outlet connecting pipes(Φ368 × 35,12 Cr1MoVG).

Platen SH is located at the top of furnace and is all-radiant heating surface. 12 pieces of platen SH are arranged along the furnace width, with a transverse pitch of 1610(S1=1610) and a longitudinal pitch of 53.4(S2=53.4). In order to reduce heat deviation among tube panels of the same piece, each piece of tube panel along the furnace depth is composed of 4 small platens. And each small platen is composed of 16 pipes of Φ44.5×7 and coiled into U-shape. Materials of 12Cr1MoVG, SA-213T23, SA-213T91 are respectively adopted from inlet section to outlet section and stainless steel of SA-213TP304H is employed for pipes in the 3 outer loops and packing pipes at the bottom of the platen.

All-radiant platen SH will directly absorb the radiant heat from the furnace. In this way, inherent characteristics of radiant SH and convection SH will be combined and a relatively smooth characteristic curve will be reached within a guaranteed temperature regulation scope.

In order to ensure flatness of tube panels and reduce slagging, platen SH tube panels are arranged with sliding blocks. Meanwhile, they are also arranged with 8 steam-cooled radar tubes to ensure spacing among platens. After being drawn out by platen SH inlet main pipe, the 8 radar tubes will enter the furnace respectively from both sides of the roof, pass through the pipe in front of every small platen and finally enter platen SH exit main pipe.

Platen SH will transfer the load to boiler top plate through high top plate hanging devices. The pipes passing through the roof are of all-welded sealing construction. The sealing plate will not bear any load and only be used as primary sealing elements.

Platen SH adopts the mode of flexibly connecting header with main pipes, which means that every three pieces of platen SH led out by one inlet header will enter one outlet header and the inlet and outlet header will be connected respectively with the inlet and outlet influx header by connecting pipes.

4) High-temperature superheater

Superheated steam will pass from the front & rear platen SH outlet influx headers to high temperature SH inlet header (Φ609.6 × 75, 12 Cr1MoVG) respectively from SH secondary attemperators (Φ609.6×75, 12 Cr1MoVG) and SH secondary

attemperator outlet connecting pipes (Φ609.6 × 65, 12 Cr1MoVG). After heated by high temperature SH, the superheated steam will then enter high temperature SH outlet header (Φ609.6×85, SA-335P91) and finally flow from the two high temperature SH outlet pipes (Φ450×47, SA-335P91) at the right & left sides to turbine high-pressure cylinder for power stroke in two ways respectively through the right & left sides of high temperature SH outlet safety valve pipe sections (Φ450 × 60, SA-335P91).

High-temperature superheaters are suspended at the top of the furnace arch nose. There are 35 pieces in total. The 35 pieces have an in-line concurrent flow arrangement, with a transverse pitch of 575(S1=575) and a longitudinal pitch of 61(S2=61). Each platen is composed of 17 pipes of Φ51 × 8 and coiled into U-shape. Materials of 12Cr1MoVG, SA-213T23 and SA-213T91 are respectively adopted from inlet section to outlet section and stainless steel of SA-213TP347H is employed for pipes in the outer 3 loops.

Like platen SH, sliding blocks and steam-cooled radar tubes are arranged in high temperature SH tube panels to ensure tube spacing and flatness and reduce slagging. High temperature SH will transfer the load to boiler top plate through high top plate hanging devices. The pipes passing through the roof are of all-welded sealing construction.

In order to keep the wall temperatures of all materials of high temperature SH within their permissible temperature scopes, orifices are adopted in high temperature SH to regulate the flow rate between the inner and outer pipe loops of the same tube panel so as to maintain an approximately close wall temperature among pipes. The orifices are opened on high temperature SH inlet headers with specifications of Φ24 and Φ20.

2.3.9 Regulation of Superheated Steam Temperature

2.3.9.1 The rated temperature of superheated steam can be kept under load of 50% BMCR~100% BMCR, with ±5℃ temperature difference permitted. The deviation of the right and the left outlet steam temperatures shall be less than 5℃.

2.3.9.2 Two-stage spray attemperation shall be adopted to adjust superheated steam temperature. The primary attemperation shall be arranged at the inlet of platen SH for coarse adjustment, while the secondary attemperation shall be arranged at the inlet

of finishing SH for fine adjustment. When the high pressure heaters are out of service, large amount of spray water must be fed via the primary attemperator to protect the platen SH and finishing SH from being overheated.

2.3.9.3 For the secondary attemperation, temperature drop value may be set as 7℃. In order to prevent the occurrence of steam condensation and water forming after attemperation, the steam temperature after the primary attemperation shall not be under the saturation temperature plus one margin（△D）under operation pressure. When the pressure is less than 12.1Mpa, △D shall be at least 28℃. When the pressure is more than 17.6Mpa, △D shall be at least 14℃. Under intermediate pressure, △D value may be calculated by linearity difference. In case the primary attemperation could not meet the steam temperature requirement, then the desuperheating extent of the secondary attemperation may be enlarged.

2.3.9.4 Under 20%BMCR, the primary attemeration shall be out of service, and under 10%BMCR, the secondary attemperation shall be out of service.

2.3.9.5 The open degree of back pass gas damper shall be adjusted according to boiler load fluctuation. Close the gas damper at one side when adjustment of gas damper towards close side is needed, and don’t close the gas damper at SH and RH sides at the time.

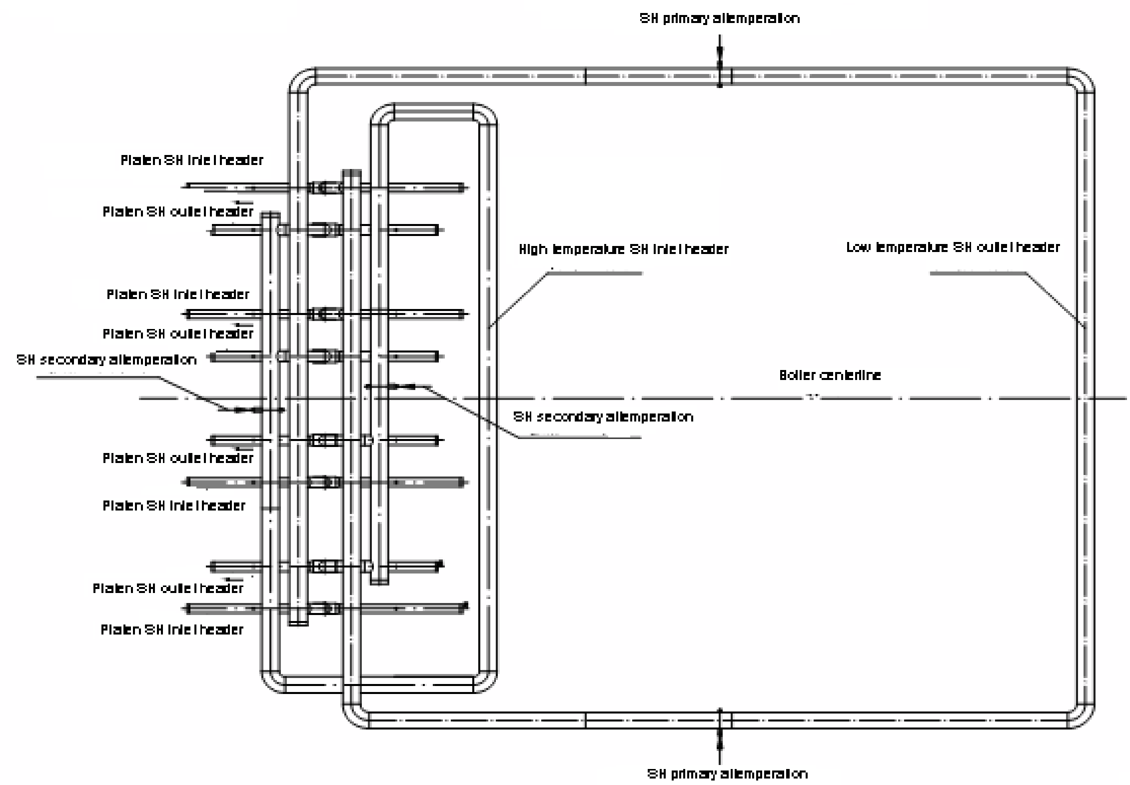


Figure 3-3 Layout of the two cross and two-stage spray attemperation in SH system

2.3.10 Reheater System

Reheater system can be sequentially classified into low temperature RH and high temperature RH according to steam flow.

1) Low temperature reheater

The steam exhausted from the turbine high pressure cylinder will pass from the two safety valve pipe sections (Φ762 × 35, SA-106C) and the two conduits (Φ762 × 30, SA-106C) at the inlet of low temperature RH at the right and the left side to the low temperature RH inlet header (Φ762× 45, SA-106C) located in the gas duct in rear vertical shaft and then to low temperature reheater coil pipe.

Located in the BP front gas duct, low temperature reheater can be classified into horizontal and vertical sections. The horizontal section has an in-line counterflow arrangement, with three pipe groups. A certain maintenance interval is kept between pipe groups. The first pipe group in horizontal section are pipes of Φ63.5×5/6, SA-210C, with a transverse pitch of 115(S1=115) and a longitudinal pitch of 87.3(S2=87.3). There are 5 clamp pipes and 178 platens. The second and third pipe

groups in horizontal section are pipes of Φ63.5×5/6, 15CrMoG, with a transverse pitch of 115(S1=115) and a longitudinal pitch of 87.3(S2=87.3). There are 5 clamp pipes and 178 platens. When low temperature reheater enters the front reversing chamber, every two rows of pipes will be integrated into one row so as to form a vertical outlet pipe section. The vertical outlet pipe section are pipes of Φ57×4.5, 12Cr1MoVG, with a transverse pitch of 230(S1=230) and a longitudinal pitch of 79(S2=79). There are 10 clamp pipes and 89 platens.

Low-temperature RH header is arranged in BP front gas duct and connected to BP side wall lower header by U-shape climbing pole. The anti-twist device of low temperature RH header is arranged in cold structure. The pipe groups at horizontal section of convection SH are suspended under the girder by economizer hanger pipes while the vertical outlet pipe sections are suspended on the top plate by lugs.

The pipe groups at horizontal section of convection SH are suspended under the girder by economizer hanger pipes. According to flue gas temperature, the material of ZG1Cr18Ni9Ti is employed for support pieces for the pipe groups in horizontal section. The vertical outlet pipe sections are suspended under the girder by lugs.

In order to maintain an approximately close wall temperature among RH pipes. Orifices are opened on low temperature RH inlet headers with specifications of Φ23mm and Φ28mm.

2) High-temperature reheater

The steam will pass from low-temperature reheater directly to high-temperature reheater. After heated by high-temperature reheater, it will enter high temperature RH outlet header(Φ863.6 × 56, SA-335P91) and then be led out in two ways(i.e., the right and the left side) from the safety valve pipe sections (Φ775 × 40,12 Cr1MoVG)at the outlet of high temperature reheater by high temperature RH outlet pipes at the right and the left side.

High-temperature reheater is arranged in the horizontal gas duct and has an in-line counter-current arrangement, with a transverse pitch of 230(S1=230) and a longitudinal pitch of 79(S2=79). There are 10 clamp pipes and 89 pieces in all. The pipes for high temperature RH are made of four kinds of material, i.e., 12Cr1MoVG, SA-213T23, SA-213T91 and SA-213TP304H and the specification is Φ57×4.5/5.5.

High-temperature reheater is also suspended on the top plate by using high top plate construction. The tube panel passing through the roof adopts the sealing mode of V-shape plate due to small pitch among tube panels. The load of the roof is transferred through suspension loops to the end plates of the high top plates at the

front and rear rows

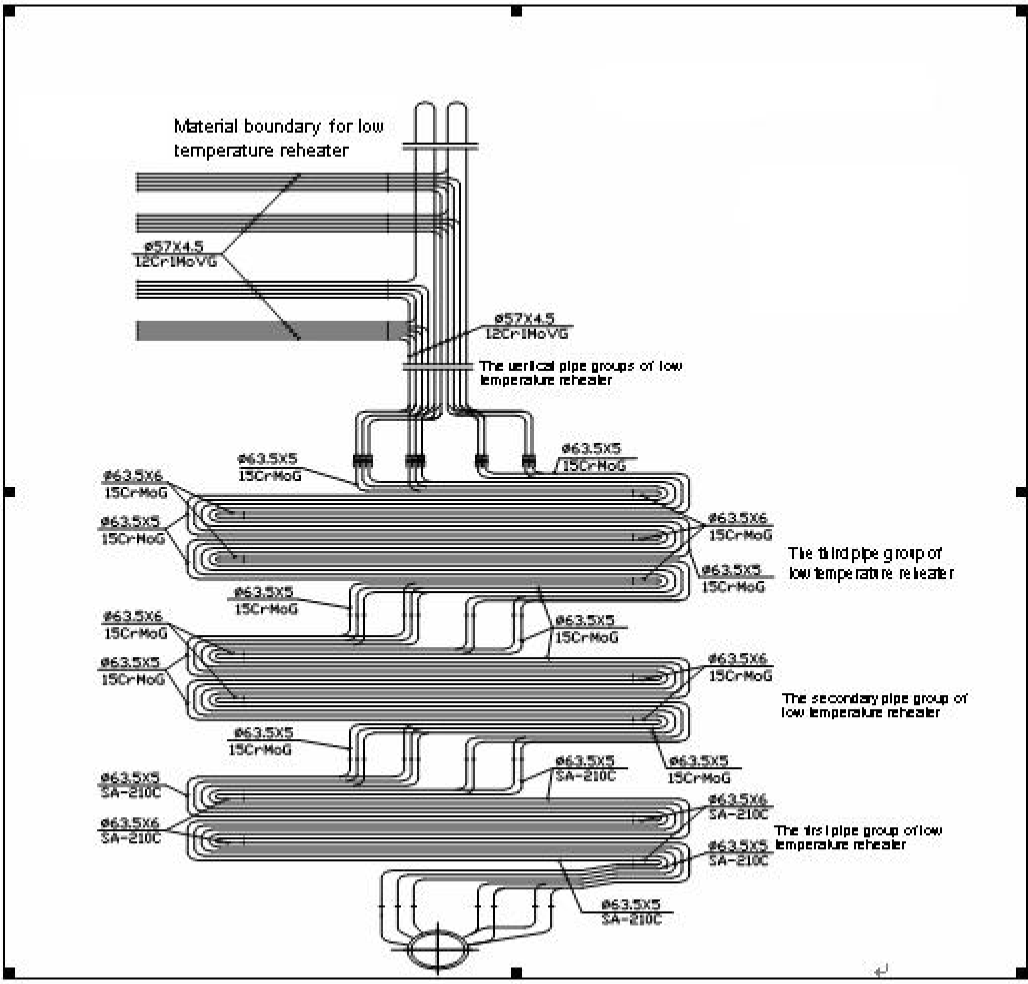


Figure 3-5 Material boundary for low temperature reheater

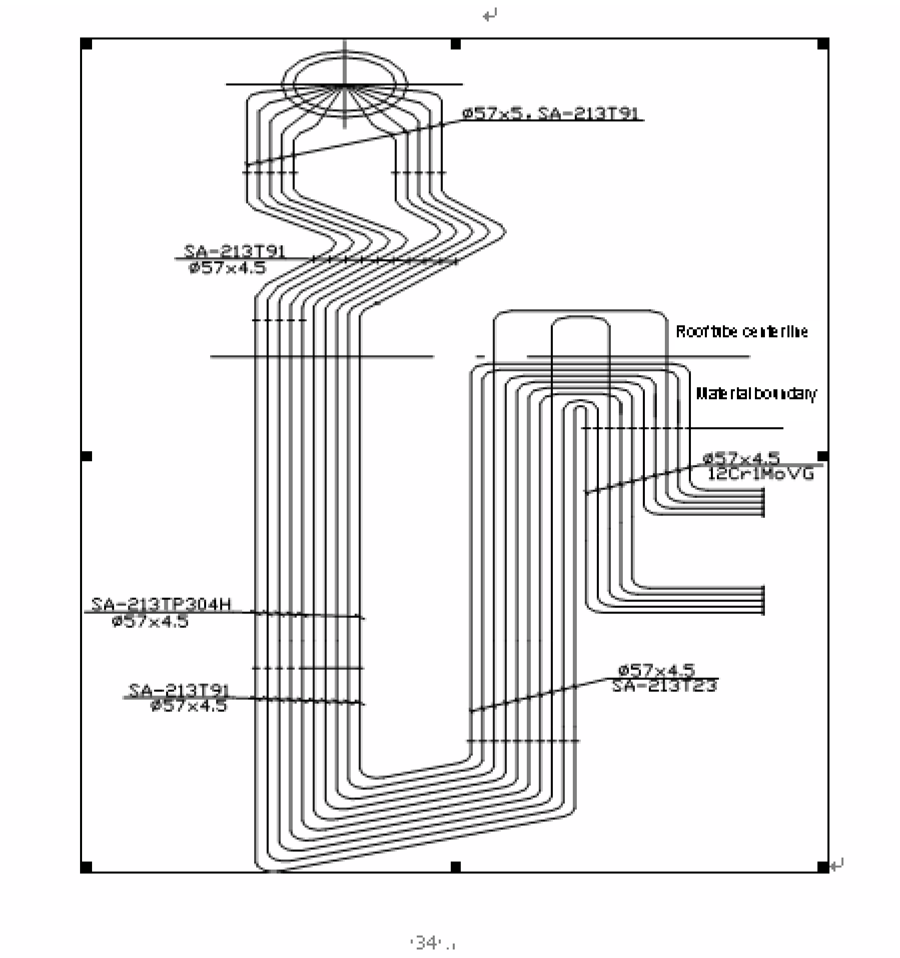


Figure 3-6 Material boundary for high temperature reheater

2.3.11 Reheated Steam Temperature Regulation

Gas-side regulation shall be adopted to control reheated steam temperature. Emergency spray attemperators shall be arranged at the inlet of reheaters to protect the reheaters from being overheated. The gas-side regulation of reheated steam temperature is mainly achieved by swinging burners or dividing gas damper. This boiler adopts dividing gas damper to regulate steam temperature.

To adjust reheated steam temperature by dividing gas duct to alter angles of gas damper is to divide the gas duct in rear vertical shaft into two parallel gas ducts, namely, the front gas duct and the rear gas duct. The rear gas duct shall be arranged with low temperature SH, the front gas duct with low temperature RH and the outlet of the two parallel gas ducts with adjustable gas damper. When reheated steam temperature changes according to boiler output or other working conditions, the open degree of the gas damper at low temperature RH side shall be adjusted and the open degree of the gas damper at low temperature SH side shall be accordingly adjusted

so as to change the flue gas flow distribution of the two parallel gas ducts. In this way, the heat absorbed by low temperature reheater can be changed and the reheated steam temperature can be adjusted to required temperature value.

2.3.12 Clamping Tube

Clamping tubes are adopted to ensure transverse relative position of tube panels and to prevent tube panels swaying in boiler. Clamping tubes are led out from the connecting pipe between convection SH and platen SH to the outlet influx header of platen header.

There are 8 clamping tubes for platen SH, with specification of Φ44.5 × 7. The material of 12Cr1MoVG is for clamping pipes at inlet section and SA-213T91 for outlet section.

There are 4 clamping tubes for high temperature SH, with specification of Φ51×8. The material of 12Cr1MoVG is for clamping pipes at inlet section and SA-213T91 for outlet section.

2.3.13 Sealing Structure for Roof-passing Tubes

The entire boiler roof adopts membrane wall tube panels so as to form a well sealed structure. Weld tube panels in workshop as far as possible. Weld flat steel on both sides of separate tubes in workshop. During site-installation, don’t weld the pressure tubes directly, instead, weld the flat steel with flat steel.

Except for high temperature RH roof-passing tubes which are to be sealed among the high top plates by V-shape plate due to structure limitation, superheater, reheater and other tubes passing through the roof and top wall enclosure shall adopt fully sealed structure.

2.3.14 Boiler Protection

During boiler operation, especially during the bad working conditions such as boiler startup and shutdown, necessary measures must be taken to protect superheaters and reheaters from being overheated and over-pressurized.

1) HP and LP Series Bypass of Steam Turbine

This unit adopts steam turbine of high-low pressure two-stage series bypass system as overpressure protection during boiler startup, shutdown or emergency (e.g., power system accident, turbine shutdown, etc.). Before turbine startup and

during emergency shutdown, the boiler is still running and the steam can go on with circulation through bypass system instead of steam turbine. The steam generated by the boiler at this moment will flow to superheater and back to reheater after attemperated and decompressed by high pressure bypass, then pass from reheater to low-pressure bypass and finally enter the air-cooled condenser after attemperation and decompression.

This type of bypass system can ensure steam flow in reheater under any working condition, which can effectively protect the reheater system. Moreover, it can also meet the antifreezing requirements of air-cooled condenser during startup in winter and operation at low load.

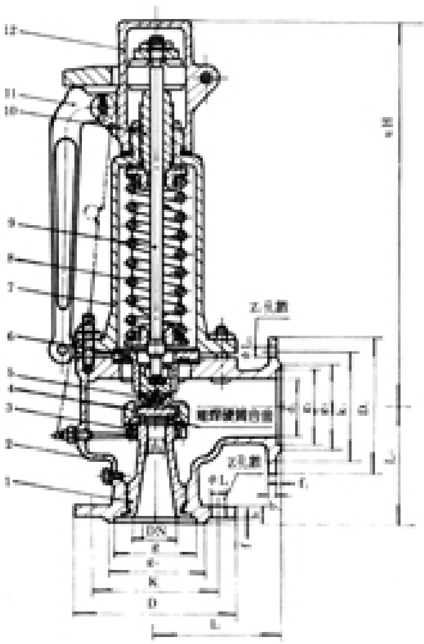
2) Emergency Balance Valve and Safety Valve

Two emergency balance valves (EBV, 1 at the right side and 1 at the left side), two spring safety valves (1 at the right side and 1 at the left side) and two exhaust valves (1 at the right side and 1 at the left side) are arranged in the outlet pipes of high temperature superheaters to serve as the main means of overpressure protection of superheaters. The steam exhaust valves are to be controlled remotely, which can make up the deficiencies of bypass capacity. On the one hand, the set pressure of the electronic ball valves and safety valves is lower than that of the drum safety valves, therefore, EBV and safety valves will trip when the boiler is over-pressurized so as to ensure a sufficient steam flow in the whole superheater system. On the other hand, the set pressure of the electronic ball valves is lower than that of the superheater safety valves; therefore, the safety valves can be protected from frequent action. An isolating gate valve is arranged in front of the EBV for isolation during EBV overhaul.

Six spring safety valves (3 at the right side and 3 at the left side) and two spring safety valves (1 at the right side and 1 at the left side) are respectively arranged in the inlet and outlet pipes of reheaters. The set pressure of the safety valves at the reheater outlet pipes is lower than that of the inlet pipes, therefore, when the safety valves begin operation, there are sufficient steam flow in reheaters to effectively protect the reheaters.

There are six（three on each side）spring safety valves which are responsible for drum safety.

All the power control relief valves, safety valves and exhaust valves have been equipped with silencers to reduce noise level. Safety valve is shown as follows:



3) Temperature monitoring

Measurement for the SH and RH is very important for protection against superheated steam and tube metal wall being overheated during boiler startup, shutdown and operation. Thermo couples mounted on primary and secondary attemperator and SH outlet tube server as superheated steam temperature monitors. Tube metal wall temperature is monitored by wall measuring temperature points fixed on exit sections of various SH heating surfaces. Reheated steam temperature is monitored by spray attemperatorr for reheater accident and thermo couples which are mounted on reheater outlet tubes. Reheater outlet wall termperatre measuing point

servers as monitor for tube metal wall temperature. The alarming temperatures of SH, and reheater tube metal are shown as the following table:

measuring point location	number of measuring point	tube diameter dw×S(mm)	material	alarming temperature(℃)
Low temperature superheater outlet	6	Φ57×7	12Cr1MoVG	474
platen superheater outlet	44	Φ44.5×7	SA-213T91	579
high temperature superheater outlet	40	Φ51×8	SA-213T91	590
high temperature superheater outlet	24	Φ57×4.5	SA-213T91	617

4) Gas temperature probe

During boiler startup, there is no steam passing through the reheater when the bypass system has not been put into service. Meanwhile, the reheater wall temperature must be strictly monitored for the sake of worse working condition on reheater. Therefore, there are two gas temperature probes mounted on the boiler front wall to monitor gas temperature during boiler startup, to ensure no overheating would happens on various heating surface during boiler startup. The alarming temperature of gas temperature probe shall be 540℃ and retracting temperature shall be 580℃.

2.3.15 Combustion equipment

This unit is integrated with opposite firing technology with middle speed milling pressurized direct pulverizing coal system. There are six ZGM113G middle speed pulverizers (one as spare) in total.

Coal fineness: R90＝16%

30 OPCC low NOx Dual Channel Swirl Burners are separately mounted on the boiler front and rear water walls in three layers. There are five burners on every layer. Interaction between burners have been fully considered during arrangement period: the distance between burner layers shall be 4400mm and the space between columns shall be 3680mm. the distance between upper burner central line and platen bottom is 18947mm. the distance between lower burner central line and bottom ash hopper breaking point is 3250mm; the distance between the most lateral burner central line and side wall is 2990mm, which could avoid side-wall slagging as well as high temperature erosion. Several air boxes equipped on the burner. Air box is classified as front wall air box and rear wall air box. According to the number of layers arranged on front and rear walls, the front or rear air box is divided into 5 smaller air boxes, in another word, there is a small air box on burner each layer. Wind is conducted through two sides of the furnace for every small air box (refer to the following figure)

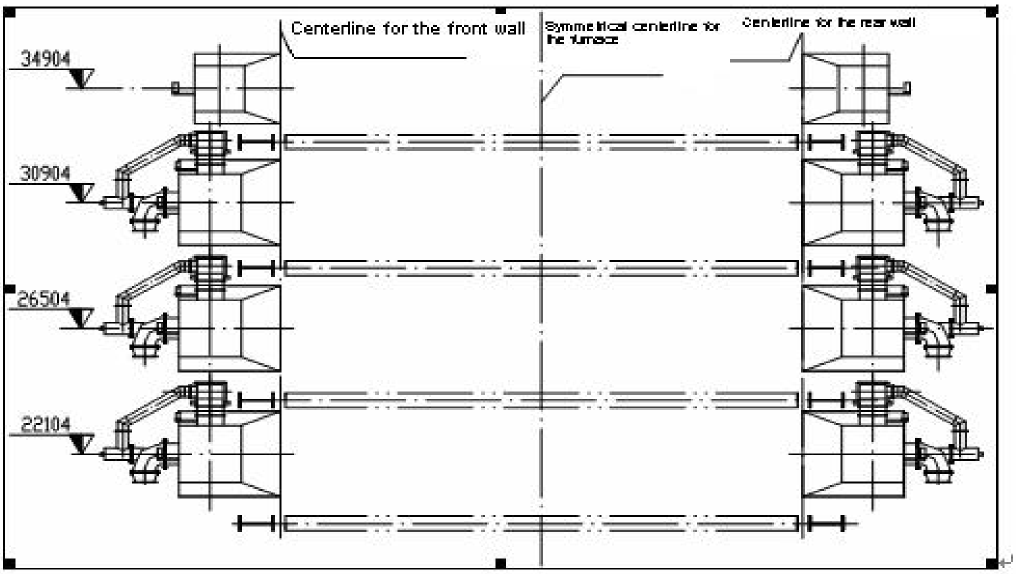


Figure 3-7. Combustion equipment layout

Five burners on the same layer connect with one pulverizer. Burner operation and shutdown are synchronized with those of pulverizer. 25 burners are able to meet full load requirements.

Over-fire air register is arranged on upper part of the burner. 10 over-fire air registers are separately mounted on front and rear walls, five on each wall, and arranged into

one row. The distance between over-fired air register central line and the uppermost burner central line is 4000 mm.

2.3.15.1 Characteristic of structure

Boiler combustion equipments consist of coal powder burner, over-fire register, big air box, fuel device, pneumatic actuator and etc.

a) Burner (shown in figure2-1 and 2-2): air supplied for burner is classified as primary air, secondary air, tertiary air and central air, which is supplied separately for the furnace through primary air duct, concentric secondary air in burner, tertiary circular duct and central duct during different combustion period. Especially, 2 axial swirler are fixed in the secondary air duct. Tangential swirling technology is integrated into tertiary air process, which can be used for adjustment to swirling intensity.

Figure 2-1 Inner structure of pulverized coal

Figure 2-2 Structure of pulverized coal burner nozzle

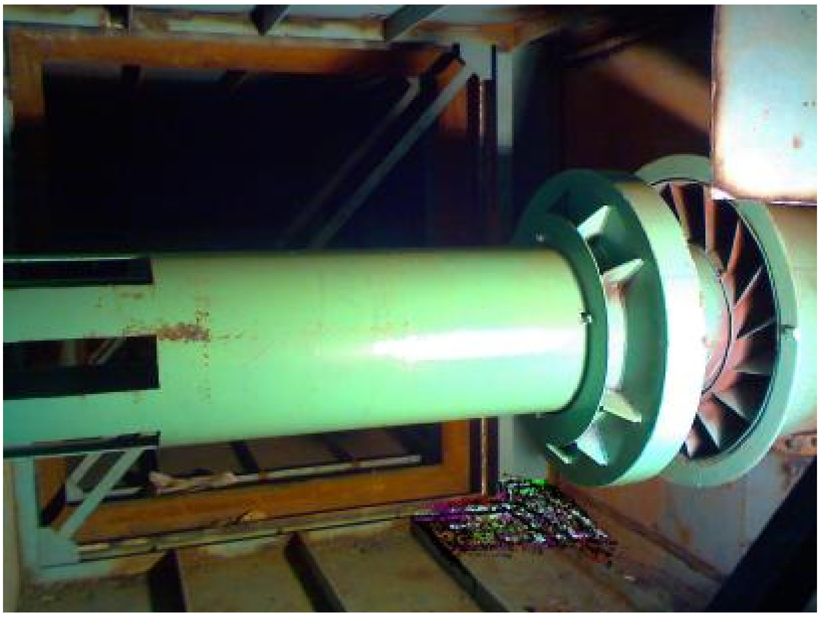


Figure 2-3. Inner structure of over fired air adjusting equipment

b) Over-fire air register (refer to figure 2-3): air supply for over-fire air register consists of inner part and outside part. Central part represents for direct air. Outside part belongs to swirling air.

c) Central air duct: air is conducted by central air main duct through two sides of big air box, connects with central air duct in the burner through various branches and servers operation of oil gun with required air.

d) Pneumatic actuator for damper:

Pneumatic actuators are equipped at big air box (including secondary air box and over-fire air box) inlet damper, which could be adjusted continuously. There are total 16 such pneumatic actuator in the furnace. The total number of damper actuators of central air main duct is 12.

e) Big air box: secondary air required by combustion comes from the big air box which consists of six secondary air boxes and 2 OFA air boxes. Secondary air from air preheater is conducted into front and rear wall air boxes by means of crossing boiler lateral air duct. Each air box is responsible for supplying air for 5 burners in one layer or over-fire air register.

f) Fuel device: two-stage ignition method is adopted by the boiler. That means: light oil gun shall be ignited by high-energy ignitor, and coal powder shall be ignited by light oil gun. Every burner shall be equipped with one oil gun. Pneumatic shall be supplied for oil gun and combined high-energy ignitor, which is mounted in the central air duct of the burner.

The total designed volume of oil gun is equal to 30% of BMCR boiler heat input, which is used for ignition, furnace warming and meeting the low-load combustion-assistance requirements. Each oil gun capacity is 1350kg/h. oil gun is atomized by mechanical measures.

2.3.15.2 Layout and structural characteristic of the burner

The structure of Type OPCC dual channel low NOx swirl burner is shown as the following figure 3-8, which consist of primary air duct, inner secondary air duct, outside secondary air duct, swirl control system, central air hoe and throat area. Primary air jet is made from anti-burnt wear-resistant stainless steel SUS310 (1Cr20Ni14Si2). Smooth and good heat conductive silicon carbide bricks are paved around throat surface. These bricks are suitable for high temperature and abrasion conditions and can significantly reduce throat surface temperature in contrast t with normal fire-proof materials and avoid occurrence of slagging around throat area.

Each low NOx swirl burner is equipped with one oil burner which is used for ignition, furnace warming and keeping combustion stable under low load condition. Every oil burner is equipped with high-energy ignitor. The high-energy ignitor, oil burner and their propellers are combined as whole. Mechanical atomization technology is adopted for the oil burner which has a capacity of 1450kg/h.

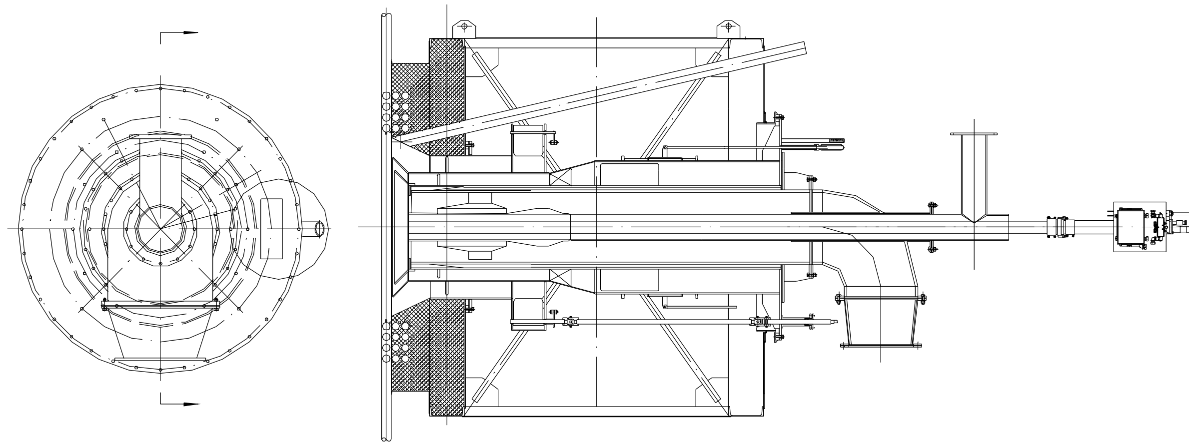


Figure 3-8 low NOx swirl burner

Air supply method for Type OPCC dual channel low NOx swirl burner is shown as follows:

1）primary air

Firstly, the powder mixed with primary air will enter the primary air bend of the burner, and then pass through the burner primary air duct as well as coal powder concentrator located in primary air duct. Coal powder air flow will be separated along radial direction. Concentrated pulverized coal air flow will be conducted from primary air duct circumferential outer side to flame holder, guide cone located at primary air duct outlet and reach to circular return area for combustion; dilute pulverized coal air flow will be purged into the furnace through primary air duct central area, and begin to combust inside circumfluence area

Primary air and secondary air will be separated by Primary air guide cone and expanding cone and formed into an included angle in which a stable circular circumfluence area caused by high speed primary air and second air will be produced. Because this circumfluence area is close to primary air outlet, the temperature of circumfluence gas will be rather high; heat required for ignition will be reduced due to concentrated pulverized coal air flow which enters into the circumfluence area; the turbulence of pulverized coal air flow will be improved by flame holder mounted at nozzle outlet, which could further improve ignition speed of pulverized coal air flow; mixture with secondary air will be delayed through primary air expanding cone to improve temperature of circumfluence area. Therefore with such factors above, pulverized coal air flow could be ignited quickly and timely, and begin to combust stably after leaving from burner nozzle.

2）inner secondary air and outer secondary air

Inner secondary air and outer secondary air for burner operation will be supplied by

burner big air box. Inner secondary air and outer secondary air will be supplied through the inner secondary air duct and outer secondary duct which are concentric in the burner. Therefore, production of Nox will be decreased. The total inner secondary air and outer secondary air could be adjusted by their governing mechanisms mounted on the burner to ensure each burner in the same big air box will be supplied with same amount of air. By adjustment, the inner and outer secondary air will be distributed appropriately and best combustion working condition will be realized (i.e. good ignition and stable combustion performance, effective combustion, low Nox emission and slagging prevention, etc.) .

Fixed axial swirl vane is located in the inner secondary air duct(inclination of inner secondary air swirl vane shall be 55°)，by which inner secondary air will be swirled. Swirling air will be expanded due to centrifugal force when it gets out of the burner. Therefore, high tempera gas will begin to recirculate due to subatmospheric pressure which happens at central area. Energy for pulverized coal air flow ignition will be supplied through this way. The circular vane on outer secondary air swirl device is adjustable with an angle of 65°. Requirements for burner swirl strength and flame shape will be met by adjustment to inner secondary axial sleeve position by which the proportion of swirl air to outside secondary air could be modified.

The best position for inner and outside secondary air damper shall be identified during combustion commission. No adjustment shall be necessary unless there is significant change on coal quality.

3）central air

Central air duct located inside burner are equipped with Oil gun and high-energy ignitor, etc. Small flow rate of central air duct will be conducted into the furnace through central air duct as supplied air for fuel during oil operation; central air duct serves as adjustment to burner central circumfluence area position for best combustion working condition by controlling pulverized coal igniting point. Central air for every burner shall be supplied by central air main duct at the same layer. Air dampers have been mounted at central air main duct for adjustment purpose. Air damper shall be operated manually during the oil gun operation, and switched to auto adjustment mode when oil shutdown.

4) Over-fire air (OFA)

Air of OFA inlet covers two separated air flows: non-swirling air flow in central part, which is directly conducted into the furnace; air flow swirls around outside area, which is used for mixture with rising gas flue near furnace water wall. Separative degree

between outer circle swirl strength and the two air flows shall be easily adjusted by a lever. The best position for the lever shall be set during combustion commission at boiler trial operation stage.

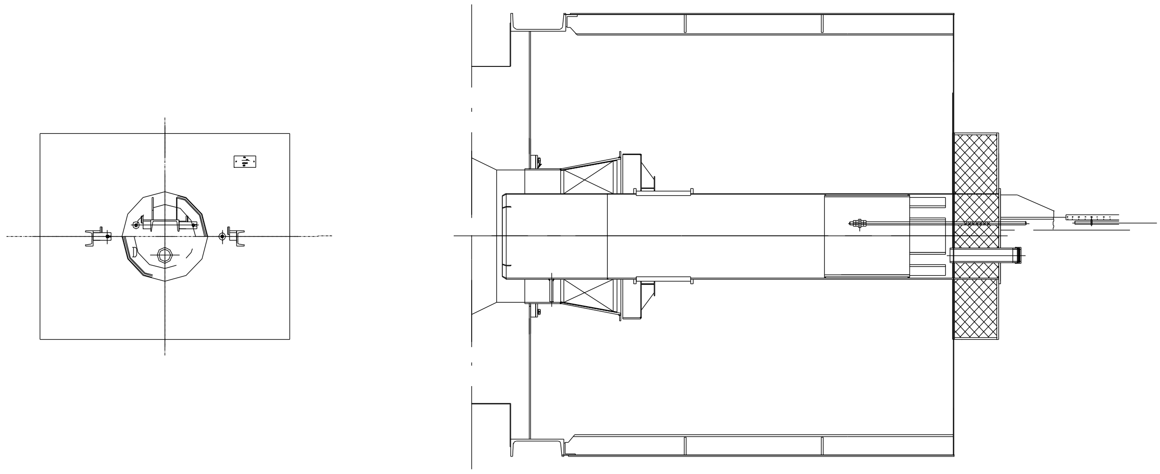


Figure 3-9. Over fired air adjusting equipment

2.3.15.3 Burner Adjustment

Burner secondary air damper and tertiary air vane could be adjustable. When best burner performance is guaranteed during combustion commission at trail operation stage, no further commission shall be needed unless significant change on fuel happens. NOx emission will be controlled by modifying the chemical equivalent of the burner, or in other words, it will be controlled by adjusting the air proportion between burner and OFA.

2.3.16 Steel construction of the boiler

Boiler structure is designed according to standards as earthquake intensity XI, type II site, basic air pressure 420N/m^2 and type B ground roughness.

The whole boiler structure is made from steel. Main components are connected with each other by high strength bolt hexagon nuts. For those less important connections, welding method is implemented. The boiler is equipped with light metallic roof, sealing big cover and operating-water chamber, etc.

Boiler structure is designed according to national “Code for design of steel structures” and standards issued by American Institute of Steel Construction（AISC）. Earthquake-resistant measures and air load consideration has been integrated into boiler structure design according to “Code for seismic design of buildings” and “Loading code for design of building structures “. Boiler structure can not only bear loading from boiler proper(including air preheater), rain and snow, and earthquake,

but also loading from various water or steam pipelines, gas or pulverized coal ducts, sootblowing equipments, boiler bounding wall enclosure and ceiling bounding enclosure, cement platform at operation layer and elevator pit, etc.

Major bearing components are made from Q345B low alloy steel, and other parts are made from plain carbon steel. Arrangement of boiler platform can meet the requirements for maintenance and inspection. Enough strength and stiffness for platform, walkway and stairs shall be guaranteed. Live load for operation layer platform is 10kPa, and 4kPa for maintenance platform; 2.5kPa for other platforms; 2kPa for stairs.

2.3.16.1 Top plate

Major loading for boiler is concentrating at top plate (roof girders). Boiler steel structure consists of roof, column, girder, vertical and lateral supporting while the roof consists of girder, secondary beam, trabecula and forming a firm box.

The stoplog style main girder is with a maximum section of H5540×1500×40×120, with a maximum length of 28900mm, with a maximum lifting of 92t, and with material of Q345B.

2.3.16.2 Columns and girders

Internal pillars of the structure are designed for bearing, while the external pillars are designed to reinforce the entire stability of structure by connecting with girders, lateral supporting and internal pillars. There are 7 rows. Bolt and welding are employed in the connection of structure.

Maximum column section is H750×1150×30×100 and maximum length is 20200mm; net weight is 44t and the material is Q345B.

2.3.16.3 Structural connection and high-strength bolts

High-strength bolts combined with welding are employed for boiler framework connection. For installation connectors between primary girder and secondary girder, and among column joints, columns and girders, vertical supporting and column, torsion and shear type high-strength bolt is employed. For other parts, welding method is adapted for connector installation.

High-strength bolt diameter is classified into two types: M22 and M24. M24 bolts are employed for connection between top plate primary and secondary girders and among columns. M22 bolts are used for other cases of connection. The high strength bolt is of 20MnTiB, and the nut is of 15MnVB or 35# steel. Anchor bolts are employed for fixing column base, with 4 bolts employed for each column base.

2.3.16.4 Back stay

Furnace and wall enclosure are employed to ensure safety for pressure fluctuation inside furnace and pulverized coal explosion. Along furnace and tube wall of rear vertical shaft area, multiple-layer horizontal back stay and two sets of vertical back stay shall be arranged. Furnace designed pressure is considered as above ±5.8kPa. Max instantaneous affordable pressure is considered as above ±8.7kPa. A layer of back stay is mounted every 3 meters of furnace and wall enclosure. In addition to cold ash hopper back stay, Ⅰ850×300×12×30section with Q345B material is mainly used. For weaker parts as lower horizontal gas duct, anti-vibration frames are employed in furnace and vertical shaft space. The sections of cold ash hopper back stay at furnace bottom are Ⅰ600×225×12×20 and Ⅰ1000×350×16×30, which is parallel to the cold ash hopper and is connected to the frame; roof back stay is mounted for rear vertical shaft top to improve pressure bearing capability of water wall and wall enclosure components.

2.3.16.5 Platform stairs and guard plate

Accessible maintenance platform shall be provided for those equipments to be maintained with firedoor holes and measurement holes except those 12 main platform layers arranged for elevator. Chequer plate platform is allocated for water operation chamber, and grid platforms allocated for the others. Platforms will be connected with each other by stairs.

Aluminum alloy corrugated sheet with thickness 1mm is used as the skin casing to protect the furnace wall against damage caused by weather，by which the heat loss will be reduced and appearance of the furnace will be improved. Economizer is regarded as framework guard plate or additional lagging materials.

2.3.17 Furnace wall, insulation and boiler roof sealing

Furnace wall and insulation are major components for boiler equipments. To ensure boiler unit normal operation, Reasonable structure and appropriate construction is very necessary. Requirements for heat resistant, heat insulation, expansion and surface protection shall be fully considered during dealing with furnace wall and lagging construction, selection of furnace wall and lagging materials, and construction of furnace and insulation work.

The scope of boiler furnace wall and insulation work covers: boiler proper, rear gas duct as well as pipelines included by the boiler proper. For the sake of protection, the

surfaces of furnace wall and insulation work are all covered with metallic guard plates.

Boiler sealing is defined as metallic sealing parts that are cable to absorb multi-direction thermal expansion, which is used for avoid leakage of furnace dust and prevent outside cold air from entering into the furnace. Safety and economy of boiler operation will be affected directly by the quality of sealing. Membrane tube panel is adopted for resolution to large scale sealing issue for boiler proper. However reversed U type suspension structure is employed in this work, there are too many tubes at top of the boiler. Meanwhile density of climbing poles is very high at ceiling and heating surface. Therefore many difficulties are brought to the designation of boiler top sealing and installation due to the complicated roof structure. Boiler sealing performance will be guaranteed as ceiling sealing designation is well planned.

Boiler roof sealing designation consists of two parts. One is air sealing that is formed by high temperature gas interface of water wall, SH, RH, tubes and economizer suspension tube at roof, which is used for isolating hot gas; another one is insulation sealing for various headers and tubes. The former is called as primary sealing and the latter is defined as secondary sealing.

Boiler roof primary sealing means that metallic parts are employed for sealing purpose at roof wall bottom and seam as well as where all the heating surface systems are crossing the ceiling. For primary sealing, in case of adaptation for various thermal expansion under different temperature for various wall-crossing tubes, and pressure from gas side, different all-welded and expandable metallic sealing shall be employed to avoid gas leakage at the place where tube is passing through the wall. Roof secondary sealing is defined as big covering shell structure to be mounted on roof and its header tubes for the purpose of insulation. After above mentioned roof sealing structure being employed, roof sealing works will be accomplished as expectation.

2.3.18 Sootblowing system and gas temperature probe

Sootblowing system adopts 48 long retractable soot blowers, 10 half-long retractable soot blowers and 42 furnace soot blowers which are manufactured by Diamond Power Hubei Machine Co., Ltd. Long retractable soot blowers are arranged symmetrically at high temperature SH, high temperature RH, low temperature RH, low temperature SH. Half-long retractable soot blowers are located at side walls of rear gas duct economizer area. Furnace soot blower is mounted on burner area side

walls, and front walls and rear wall above the burner. Specification for soot blower is shown as the following form.

type	purge radius (mm)	Purge angle	soot blower journey (mm)	number	installation position
V04	～2200	360°	255	42	furnace
PS-LL	～2000	360°	10380	48	high temperature SH, high temperature RH, low temperature RH, low temperature SH
PS-SB	～2000	360°	5053(covered depth 10350)	10	economizer area

Four soot blowers for rotary air preheater are arranged at cold end and hot end of the air preheater.

Sootblowing system consists of one decompression station which is equipped with pneumatic pressure reduction valves, safety valves, pressure switches and flow switches, etc.

Steam source for sootblowing system for both boiler proper and air preheater are from primary SH outlet header. Steam source will be depressurized by the decompression station and the pressure will be kept at 0.8～1.5MPa with TEMP≤350℃. Auxiliary steam source will be adopted by air preheater during boiler startup or operation at low load.

Temperature controlled thermodynamic type drainage mechanism is adopted by sootblowing pipeline drainage system. Thermodynamic steam trap will be switched on or off automatically by temperature controller. Thermodynamic steam trap will be shut off automatically when overheating temperature has been set for pipeline steam.

2 gas temperature probes are mounted on the front wall at furnace outlet, which are used for monitoring gas temperature at furnace outlet to prevent heating surface from being burnt.

Chapter 3 Pulverizing System

3.1 Summary

Cold primary air positive pressure direct blowing system has been adopted by boiler pulverizing system of India N plant 2×600MW coal fired unit. The working procedure is described as follows: raw coal dumped from coal bunker is sent into the coal feeder after passing an electric operated gate, and get rolled and weighted with coal feeder belt, then get into the mill though the coal chute and get pulverized. During pulverization procedure, powder coal will be warmed and dried by primary air which comes from the lower part of the mill. Pulverized coal will be carried by primary air to the extractor which is located at the mill top, and be separated inside the extractor. Qualified pulverized coal will be brought out by the primary air and sent into the furnace for combustion across the burner at some certain air-coal ratio and velocity as well as temperature. Unqualified pulverized coal will be returned to the mill for re-pulverization.

Pneumatic baffle plate is adopted by the mill outlet valve. Burner Management System（BMS）and furnace safety system（FSSS）are responsible for switch control, which can cut off fuel entrance to the furnace swiftly.

Mill air volume will be adjusted by air-blend regulating baffle located at mill inlet. Outlet temperature of the mill will be controlled by cold and hot air regulating baffle located at cold and hot air duct of the mill inlet.

In case of direct pulverizing coal system, to avoid the pulverized coal leakage, cold air shall be conducted from main pipelines of the primary air fan outlet as sealing air for the mill. The purpose of mill sealing air includes: sending air to the mechanical maze seal and grinding roll to prevent pulverized coal against leaking through gaps. Meanwhile, the sealing air will be sent to the coal feeder to avoid coal powder leakage from observation window. Additionally, sealing air is used as sealant for pulverized system baffles such as hot air isolation baffle and regulating baffle to avoid the leakage of primary air.

3.2 Raw coal and pulverized coal

Raw coal is the most primitive object to be processed during operation of thermal power plant. Variations on raw coal characteristics will affect the whole production procedure of thermal power plant, boiler output power and efficiency, unit efficiency and maintenance cost, as well as economy and reliability of the whole thermal power plant.

Heat value, humidity and grindability index of coal will affect output and operation method of the mill. Raw coal ash size and component will affect rolling parts and service life as well as maintenance cost directly. The size of volatile matter will result in effects on ignition stability and combustion working conditions inside the furnace. Therefore, requirements for steam temperature, air supply method for SH and RH, as well as pulverized coal size for combustion will be affected.

3.2.1 General characteristics of pulverized coal

1) Absorbability: pulverized coal is regarded as cluster formed by small irregular particles. Generally, the size of pulverized coal is less than 300μm, and mostly less than 100μm (especially as 20~50μm). Unlike other particle cluster, pulverized coal is dried out inside the pulverized system and humidity will be limited at 0.5~1.0Winh (moisture inherent). Therefore, dry pulverized coal possesses significant adsorption capacity for air.

2) Fluidity: the nature of freshly pulverized coal is slack. The natural angle of slope is 25°~30°when it is deposited naturally. The nature packing density of pulverized coal shall be 700kg/m^3 after air absorption. For those pulverized coal deposited for a long time, the packing density will be 800~900kg/m^3 due to poor fluidity. Dry pulverized coal can pass through tiny gap due to its good fluidity. Therefore tightness for pulverizing system shall be considered into designation and operation for pulverizing system. Otherwise gravity flow of pulverized coal will cause trouble for boiler adjustment and operation.

3) Hygroscopicity: dry pulverized coal can absorb water from ambient environment, which is called hygroscopicity. The conductivity, autohesion and in particular the fluidity of pulverized coal will be affected after some water is absorbed. Fluidity will directly affect the normal transportation of pulverized coal.

4) Erosion: when pulverized coal flows through the pipelines and pulverizing system, various metallic surface and inner wall of pipeline will be eroded due to collision and friction resulted from pulverized coal driven by inertia force, which is called pulverized coal erosion. In the pulverizing system, erosion occurred at inner tube of extractor, guiding vane, tube wall and cone at the first bent of air flow swirl extractor inlet is very serious. Abrasion occurred at extractor cone are mostly resulted from collision of coarse pulverized coal. Those coarse particles get bounced inside the tubes. Usually, coarse pulverized coal will continues rotating instead of returning to the mill, which could cause serious abrasion to the cone part.

5) Autohesion: it is caused by electrostatic, intermolecular gravity and capillarity,

which is described as interactive force between pulverized coal particles. Nevertheless adhesion is described as attractive force between pulverized coal particles and wall surfaces.

6) Spontaneous combustion: for those pulverized coal deposited at dead zone for a long time, oxidation will happen. Volatile matter and heat will be released during heat decomposition, which will cause the increment of temperature. In another way, increased temperature will intensify pulverized coal oxidation. Poor heat dissipation will aggravate the oxidation process, and eventually spontaneous combustion of pulverized coal will happen. Pulverized coal is to be transported by air and it is the mixture of air and powder which will explode due to any occurrence of spark. In closed system, the pressure caused by pulverized coal explosion will be 0.35MPa. Therefore the designed pressure for mill and coal feeder of Yangzhou No. 2 Power Plant's stage II work is 0.35MPa. pulverized coal explosion may be caused by many reasons such as volatile matter amount, pulverized coal fineness, air and powder mixture concentration, velocity, temperature, humidity, and oxygen proportion, etc. generally, for those pulverized coal (volatile matters V_{daf}<10%, blind coal), there is no risk of explosion; however for those V_{daf}>20% pulverized coal (black coal)to which spontaneous combustion is likely to happen, the possibility of explosion will be higher. For pulverized coal, more small size will cause more explosions. For example, explosion will almost never happen for those pulverized coal (size as 0.1mm). The high volatile coal shall not be grinded too small. Pulverized coal concentration is one of the key issues that may result in explosions. According to facts, the most dangerous concentration is 1.2~2.0kg/m^3 , and the possibility of explosion will be reduced beyond this range; the temperature of air and coal mixture should be less than pulverized coal ignition temperature otherwise explosion may happen due to spontaneous combustion.

Certain inclination shall be designed for pulverized coal tubes in pulverizing system to insure that velocity of air and coal mixture is appropriate. Too low velocity may result in deposition of pulverized coal; too high velocity may cause electrostatic sparks. Therefore the velocity shall be controlled in range from 16~30m/s. the explosion possibility for moist pulverized coal is fewer. Humidity of pulverized coal is usually reflected on the mill outlet temperature. Therefore strict requirements for mill outlet temperature have been proposed by direct-fired system.

3.2.2 Fineness of pulverized coal

Pulverized coal fineness means that a certain amount of pulverized coal is screened

and weighted by a standard sieve with mesh as xμm and the percent of residual amounting for the total is defined as pulverized coal fineness R_x :

$$Rx = \frac{a}{a+b} \times 100\% \qquad 4-12$$

In formula 4-12, *a* represents for residual amount on sieve with mesh as xμm; *b* represents for the amount of pulverized coal that has went though the xμm mesh.

For a certain mesh size, the less residual amount of pulverized coal on the sieve, the more fine the pulverized coal is, or the smaller R_x is. Standard sieve used for determination of pulverized coal fineness is designated as specific sieve number and standard mesh size. Sieve number is described as mesh number which is defined as the eyelet numbers per unit length of the sieve. Different standards have been adopted by various countries, for example, 70 mesh sieve in China means that there are 70 meshes per centimeter in the sieve, namely, 4900 meshes per square meter. Different mesh sieves are weaved by metallic wires with different diameters. The approximate ratio between mesh size and wire diameter is 3: 2. As such, for those 70 mesh sieve with mesh as 90μm, the diameter of metallic sieve wire should be 55μm accordingly.

with regard to combustion, more fine pulverized coal is recommended, by which either the heat loss of gas emission or heat loss of incomplete combustion will be reduced; however, to reduce energy consumed by pulverizing system and abrasion of the mill, more coarse coal is preferred. Therefore the exact fineness of pulverized coal shall be determined according to comprehensive technical comparison between combustion characteristics of different coal and mill operation cost. Meanwhile the sum of $q_2+q_4+q_n+q_m$ gets the minimum value, pulverized coal responded to this sum shall be defined as economic fineness(q_2 as gas emission heat loss, q_4 as mechanical incomplete combustion loss, q_m as mill energy consumption, q_n as pulverizing system metallic consumption) shown in figure 4－4.

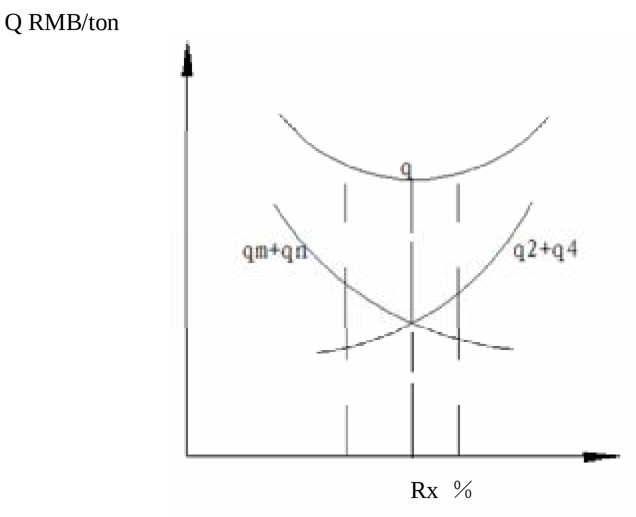


FIG. 4-1 Economical fineness

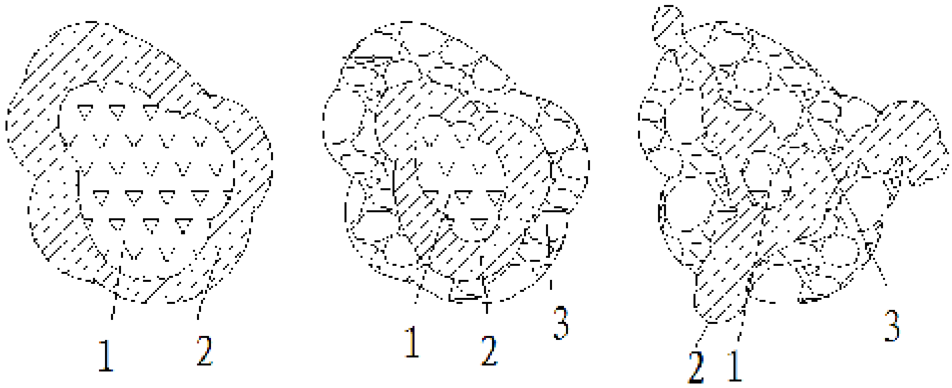
3.2.3 Characteristic indexes for coal combustion

Almost all coal property indexes are related to coal combustion characteristics. In contrast, there is no index that is complete and comprehensive to characterize coal combustion characteristics. Meanwhile, the different coal characteristic index importance for coal combustion characteristics will be varied according to the difference of coal combustion method. The difference will be significant. The most obvious indexes which will affect coal combustion characteristic or process are coal volatile matter and adhesion or coefficient of expansion. The former represents for gaseous phase share and effects on its following solid phase combustion procedure during coal combustion; the latter related to the variations of coal particle appearance, size and reaction surface, which will affect its combustion characteristics. The relationship between the former and the latter is very close. Those characteristics such as release characteristic of volatile matter, coke reactivity, coal thermal stable value, and coal weathering, spontaneous combustion and grindability during deposition, is also related with coal combustion characteristics.

1) Coal particles appear in molten form, colloid form and carbocoal form during heating.

For almost all the bituminous coal, during heating procedure and volatile matters releasing process, colloid matters will appear in plastic nature and soft particle. Adhesion between coal particles result from particle colloid matters sticking together. Therefore, coal adhesion is related with conditions of colloid matter presence. For a particle that is being heated according to certain speed and the heating procedure, heat is always conducted from its surface to the kernel during the heating procedure. At the same time, temperature of surface is always higher than that of kernel. It has been observed that appearance variation could not be noticed for different bituminous

coal until the surface temperature reaches to 320~350℃, and only for those low rank coal, volatile gas could be observed on its surface. When the temperature is raised up to 350~420℃, liquid phase membrane with bubbles will be observed on particle surface, and this membrane is just the colloid matter. When the temperature is raised up to 500~550℃, colloid matters move towards the inner part caused by the increment of inner temperature, and outside colloid matters have been turned into carbocoal due to the evaporation of volatile matters. That means, from surface to kernel, the particle has consisted of three layers as carbocoal shell, colloid matters and original coal. However this appearance is just temporary phenomenon and will not last for too long. Colloid matters will be developed and be expanded by continuous heating, and cracks will occur on the carbocoal shell, and leakage of colloid matters will happen. Since then colloid matters will develop towards the central area of particle. Bleeding colloid matters will be turned into carbocoal form until the whole particle has experienced the formation of colloid matter and carbocoal form.



1. Coal 2. Liquid colloid matters with bubbles 3. Carbocoal

Figure 4-2 Coal particle transformation in various stages during coking process.

In accordance with experiments, it is shown that lower softening temperature of coal will result in sooner liberation of volatile matters. Therefore softening temperature Tp (temperature of occurrence of liquid phase membrane for various bituminous coal)and re-solidification temperature TK (max plastic presence temperature TMax as well as being evaporated and re-solidification form temperature) are regarded as indexes for coal rheological characteristics and are also used for description for those issues closely related to coal combustion characteristics by indirect way.

2) Adhesion and coking

Adhesion means that coal sticks together or with other foreign inert materials under

oxygen-deficient circumstance. Coking property derived from coking purpose. In addition to above mentioned, adhesive ability also includes natures such as coke lump structural mechanical strength. For pulverized boilers of those large scale power plants, pulverized coal particle will be separated from each other inside the furnace. Although adhesion will never happen, surface structure and actual reaction dimension will be affected by appearance variation during plasticizing procedure. Therefore combustion rate will be affected.

3) Coal (coke) reactivity

Coal particle burnout time is equal to burnout time of coke production due to the relative swift rate of volatile matters release and burnout. Coke particle reactivity is one of the key factors that determine combustion rate. Reactivity is also called as activity, which means under certain temperature condition coal is capable of reacting with other medium such as carbon dioxide, water steam and etc.; it is a relative comparison with different coal reaction speed under same circumstance.

4) Coal washability

Coal washability is proposed from coal cleaning requirements for coal industry. In fact, it is also related with coal combustion utilization characteristics. Ash exists in different forms of segregation degree and appearance in coal. Ash segregation degree in coal means the possibility of extraction. Procedure of extracting of stone coal, ore and pyrite and fabricating low-ash, low-sulfur coal, is being called coal washability. Washing selection method is based on different ash size, density, sinking or floating for coal particle in different liquid.

5) Coal weathering and spontaneous combustion

For coal exposed in air or buried in coal seam near to the surface, its physical, chemical and technical nature will be changed under environmental effects (including oxygen in air, ground water and temperature variation of ground), which is being called as weathering. Weathering is mainly caused by oxidation of coal organics. In fact weathering process is just oxidation process too. Heat release will happen during oxidation process. If heat released from oxidation can not be dissipated in time, coal pile and seam temperature will rise up, and then reaction speed will be accelerated accordingly. Therefore heat released from reaction will increase further, which will result in further increment of coal pile temperature. When temperature reaches to igniting point, spontaneous combustion will happen in coal pile. The tendency of coal oxidation is related with coal type under low temperature condition. Usually, it is regarded that the tendency of high rank coal oxidation is few under low temperature

conditions; coal spontaneous combustion is also related with coal lithofacies. In various lithofacies, the oxidation tendency of vitrain is the maximum one, and then glance coal, dull coal, and the minimum one is silk coal; coal oxidation capacity is also related with screening composition, pyrite content, moisture, specific heat and heat released during certain amount oxygen absorption and etc. spontaneous combustion is apt to occur at those coal piles with rich pyrite, less size particle and rather slack nature.

3.3 Coal Feeder with Electronic Weighing System

3.3.1 Introduction

Boiler pulverizing system is equipped with electronic weighing type coal feeder which is manufactured by Shenyang Stock Electric Power Equipment Co., Ltd. Each pulverizing system is equipped with 6 coal feeders. This type coal feeder features with electronic weighing function and automatic control system as well as speed regulating function. Appearance and major parameters of type GM-BSC22-26 electronic weighing coal feeder is shown as follows:

Type: electronic weighing

Number: six

Equipment	Item	Unit	Specification
coal feeder	adjustment scope	T/h	
	coal feeding distance(distance between inlet and outlet central line of the coal feeder)	mm	
	inlet coal chute tube diameter/wall thickness	mm	
	material		
	outlet coal chute tube diameter/wall thickness	mm	
	material		
	feed chute flange inside diameter	mm	
	outlet flange inside diameter	mm	
	width of belt	mm	
	speed of belt	M/min	
	anti-explosion pressure	MPa	
	accuracy of coal feeding	%	
main drive	main drive motor type		
	power	KW	
	voltage	V	

Equipment	Item	Unit	Specification
	main drive motor decelerator manufacturer		
scraper chain	scraper chain motor type		
	power	KW	
	scraper chain motor power supply	V	
	scraper chain motor decelerator manufacturer		
proper sealing	sealing air pressure(pressure difference to mill inlet)	Pa	
	sealing air quantity	Nm^3/min	
trouble shooting air	trouble shooting air pressure	MPa	
	trouble shooting air quantity	Nm^3/min	
power supply	microcomputer control cabinet		
	inlet and outlet coal gate control cabinet		

3.3.2 Structure of electronic weighing type coal feeder

The coal feeder consists of proper, belt, motor driving device, sweeping device, control cabinet, weighing device, coal blockage and shortage alarming device, working light and etc. shown in figure 4-7:

Coal feeder is driven by roller. The procedure of raw coal transportation from coal hopper to mill is shown as the follows: raw coal in bunker →coal flow detector →coal hopper gate →coal chute →coal feeder inlet →coal feeder conveying belt →weighing sensing component →coal feeder outlet →mill.

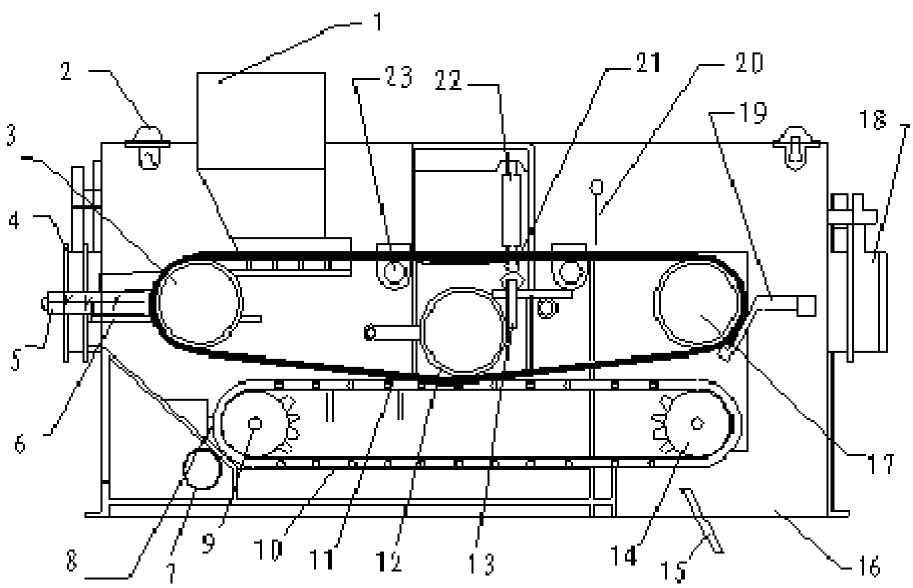


Figure 4-4 Electronic weighing type coal feeder

1. Feeding inlet 2. Light for illumination 3. Strain roller 4. Feeding gate 5. Belt strain screw

6. Strain roller base rail 7.sealing air inlet 8.scraper chain strain screw 9.strain chain sprocket

10. Cleaning scraper chain 11.feeding belt 12.tension roller 13.weighing calibration block

14. Driving sprocket 15.coal blockage signal baffle 16.outlet 17.driving roller 18.discharge gate 19.belt cleaning scraper

20. Coal shortage signal baffle 21.weighing support idler 22.load sensor

23. Support idler

Coal feeder belt mechanism consists of belt driving roller, strain roller, tension roller, coal feeding belt, belt supporting plate and etc. To ensure no left or right offset would happen during coal feeder belt operation, belt with edges and central element rest is adopted for the coal feeder belt. Roller with grooves is also equipped for the belt to ensure no guiding or moving issue would happen. Driving roller is connected to variable frequency motor. At driving roller end, scraper is provided for cleaning coal stuck on the belt. Tension roller is mounted at the middle of the belt to ensure certain tension is kept on the belt for the sake of best weighing performance. Belt tension will change according to the variation of temperature and humidity. Therefore frequent observation will be necessary. Belt tension could be adjusted by strain lever (this should be carried out at side of strain roller). Indicating panel is mounted inside the base side door. Tension roller should be centered on the central position of the indicating panel.

To get rid of coal deposited at the feeder cabinet bottom timely and avoid occurrence of coal spontaneous combustion, chain cleaning scraper mechanism is mounted below coal feeder belt mechanism for cleaning purpose. Chain cleaning scraper consists of driving sprocket, strain sprocket, chain and scraper bar, etc. scraper bar chain is driven by sprocket which is driven by decelerator. Coal deposited at feeder bottom will be scraped out and be sent to coal feeder outlet. Coal deposited at cabinet bottom includes: coal scraped by belt scraper bar, coal settlement deposited from dust and powder in air, coal swept by belt, coal blown from belt by inappropriate sealing air. Chain cleaning scraper should be put into service continuously. By this

operation method, coal deposited at cabinet bottom will be reduced. Possibility of coal level disturbance caused by lots of deposited coal entering into the mill. Additionally, continuous cleaning could prevent chain pin from being stuck and rusted. Chain cleaning scraper decelerator features with cylindrical gear and turbo deceleration. In addition to electrical overload protection for motor, cut-off mechanism is mounted between turbine and its shaft to ensure the shearing pin would be cut off and then disconnection from turbine and its shaft will be taken place and motor will be shutdown thorough limiting switch and finally signal will be sent to control room.

Coal shortage signal device is mounted above the belt. When there is no coal left on the belt, cam located at signal device shaft will be driven to rotary due to swing of signal device plate, and then limiting switch will be triggered. Therefore belt driving motor will be shut down and signal “coal shortage” will be sent to the control room..

Coal blockage signal device is mounted at coal feeder outlet, which is similar to coal shortage signal device. When coal flow gets blocked at coal outlet, limiting switch will be triggered and coal feeder will be shut down, and then signal will be sent out.

Weighing mechanism is defined as electronic weighing sensory mechanism which is installed between coal feeder inlet and driving roller. Weighing mechanism consists of 3 supporting idler and a pair of load sensor. 3 weighing idlers are all well fabricated and a pair of idler is fixed at the housing, which is formed as a weighing span. Another weighing idler is hung at the side of a pair of load sensor which is responsible for sending signals of the coal weight on belt. Below load sensors and weighing idlers, there is weighing calibration block. During coal feeder operation, calibration block supports for weighing arm and eccentric disc, which is disconnected with weighing idler. When calibration is necessary, the calibration lever may be turned, and then eccentric disc will begin to rotate so as to hang the weighing calibration block over the load sensor. Therefore accuracy of weight signal could be checked.

In case of positive pressure operation method adopted by this pulverizing system, it is working under positive pressure conditions inside the mill. To prevent hot air of the mill from being reversed into the coal feeder, special sealing air has been provided for the coal feeder. Sealing air flange interface is located at the lower part of coal feeder cabinet inlet, which is connected with sealing air duct flange. Pressure of sealing air shall be slightly higher than that of mill inlet hot air. Sealing air volume is equal to sum of air leaked from coal chute into raw coal hopper and air needed to form the pressure difference between coal feeder and mill inlet. If the sealing air pressure is too low, hot air will be conducted from mill to coal feeder, which will result in coal

deposition around the doorframe or other extrusions at risk of spontaneous combustion. Tow high pressure or too much quantity of the sealing air may cause coal blow-off and contamination on observation window.

Negative effects caused by mill hot air entering into coal feeder include:

1) Rubber aging will be accelerated due to high temperature air

2) Raw coal get burned caused by high temperature air

3) Pulverizing system efficiency will be affected as the loss of hot air inside the mill.

3.3.3 Coal feeding procedure and weighing principle

During normal operation, driving sprocket of scraper cleaning mechanism, and driving roller of coal feeder belt mechanism are rotated though their driving motor in an opposite direction. Coal from raw coal bunker drops onto the coal feeding belt below through the coal inlet, and be transported by the movement of belt, and when belt reverses, the coal on belt will be discharged to the coal feeder outlet and be sent into the mill through the coal chute. Those coal stuck on the belt will be scraped by the cleaning scraper. If inner side of belt is stuck with coal, the coal will be dropped from roller head face through self-cleaning strain roller. Coal deposited at cabinet bottom will be scraped out to the outlet through continuous operation chain cleaning scraper and be sent into the mill with that coal dropped from belt. Coal feeding amount is adjusted through adjustment to coal feeder driving motor speed. Convertor is provided for motor power supply, which could adjust coal feeding amount by altering power frequency of motor.

Coal feeding amount weighing of the electronic weighing coal feeder is realized by this algorithm.: coal weight on per length belt as G which is measured by load sensors, multiply by belt rotation speed V that is measured out by encoder, then coal feeding amount B is obtained. That means B=GV. The principle is shown as block-diagram 4-8.

An identified weighing span has bee formed by two weighing supporting idlers which are fixed on the cabinet. There is a weighing supporting idler existed between the weighing span, which is hang over at a pair of load sensors. Every load sensor is responsible for weighing half of coal on belt within the span. Output signal of the calibrated load sensor represents for coal weight (pounds or kilograms) per unit length(inch or centimeter) belt; frequency signal output by encoder that is connected to belt driving roller represents for belt rotation speed(defined as cm/s). After being amplified, output signal of load sensor is to be multiplied by frequency signal of

encoder. The product is also a frequency signal that represents for current coal feeding amount kg/s). After conversion and synthesis, an accumulated amount signal will be produced from calibrated coal feeding amount signal and be sent to the total coal amount display where the total coal feeding weight will be shown.

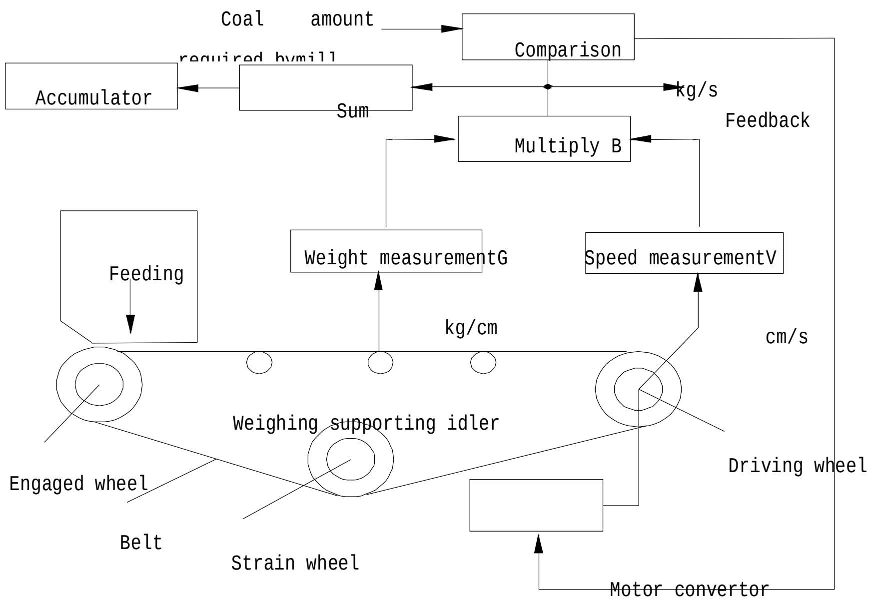


Figure.4-5 Coal feeder weighing block diagram

This coal feeder features with reverse rotation for coal discharge and volumetric weighing function. Reverse rotation for coal discharge function means that coal on belt could be discharged from the opening feeding side hole through belt reverse rotation during maintenance period. Volumetric weighing method is an option one which may be utilized automatically when there is some faults occurred in normal electronic weighing circuit. Alarming signal to DCS shall be sent when this circuit is put into service, and meanwhile coal weight should be accumulated with those signals acquired from volumetric method. However, accuracy of volumetric method is not as good as those of electronic weighing method. Therefore, volumetric measurement method shall not be recommended for long term utilization.

3.4 ZGM123N Mill

For India（NAGARJUNA）2X600MW coal-fired unit, every boiler is equipped with six ZGM123N middle speed mills that are manufactured by Beijing Power Equipment Group. According to designation, five mills are to be put into service and one for spare under B-MCR working condition. Pulverization ability of each mill is equal

to 80% amount of pulverization calculation according to coal type used for boiler designation. 20% of pulverization ability is still free.

3.4.1 Symbol

Z G M 123 N

N.G type, N - Normal，G - Greatened

Average radius of Grinding track（cm）

Mill

Grinding Roller type

Medium speed

3.4.2 Technical data of ZGM123 mill

No.	Item	Unit	N -type	G -type
1	Throughput (R_{90}=16%, HGI=80, W^{Y}=4%)	t/h	97.3	107.6
2	Nameplate Throughput	t/h	See technical agreement	
3	Rate power of motor	kW	710	800
4	Voltage of motor		See technical agreement	
5	Rated speed of the motor	r/min	990	
6	Direction of rotation of the motor		Counter-clockwise (front view of output shaft)	
7	Rated speed of the mill	r/min	23.2	
8	Direction of rotation of the mill		Clockwise (vertical view)	
9	Windage	Pa	6780	6930
10	Rated primary air flow upstream of mill	kg/s	31.08	34.37

3.4.3 Grinding principle of the ZGM mill

ZGM mill is a vertical mill with three grinding rollers and one grinding track. A grinding table rotates round a vertical axis in driven by a planetary gearbox. The three grinding

rollers, mounted in fixed position, are passed down on the table under hydraulic loading. Raw coal enters through the center of the mill and is deposited on the grinding table. Centrifugal force feeds the coal radially outward where it is ground between the roller tyres and grinding track.

The grinding force is statically determined by three grinding rollers, which is generated by hydraulic loading. The transfer loop diagram of grinding force is shown in Fig1-1. It starts from loading, to grinding rollers, grinding track, towards the foundation.

The pulverized coal is flowed by centrifuged force into the zone over the nozzle ring surrounding the table, where the coal particles are swept upwards by the stream of hot primary air into the classifier.

The intimate contact with the hot primary air causes the moisture contaminated in the coal to evaporate spontaneously. The oversize particles rejected by the classifier fall back onto the grinding table for further grinding. The fine particles, i.e. finished product, are carried out of the classifier with the air.

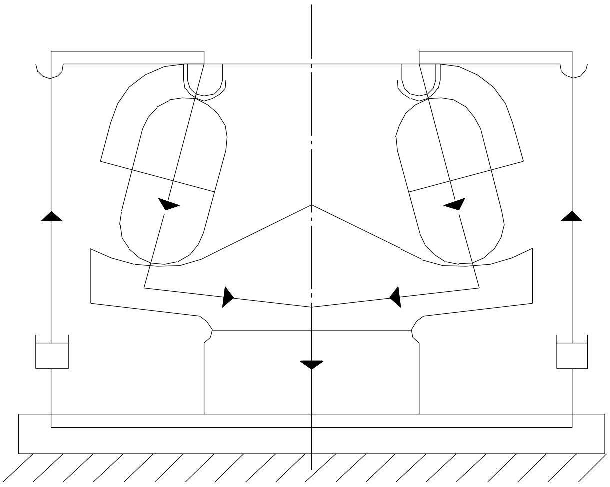


Fig. 1-1 the transfer loop of grinding force

Pyrites and tramp iron that cannot be carried upward by the primary air drop down through the ring and into the primary air plenum chamber. Revolving scraper blades attached to the bottom of the grinding table push this foreign material outward to an external disposal system (Fig1-2).

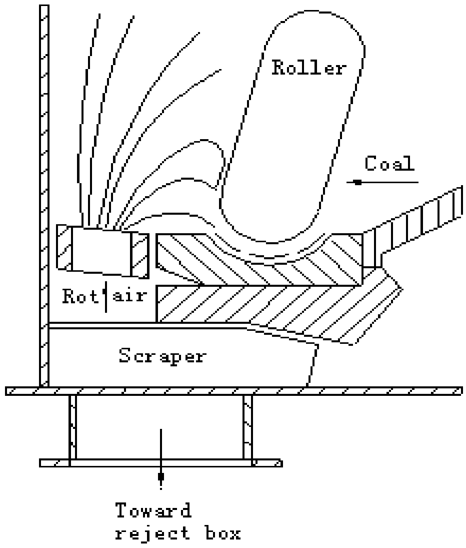


Fig.1-2 “boiling area” of mill

The ZGM123 mill is to be driven by a squirrel-cage induction motor. The torque of grinding table is driven by the vertical bevel-planetary gearbox which also stands the horizontal and vertical load caused by upper parts weight and grinding load.

In order to insure a good lubricant condition for the subassemblies inside gearbox, the lubrications unit of the gearbox is used filtrating/cooling the oil inside the gearbox.

The hydraulic unit provide grinding load，lift or put down the rollers by three tensioning cylinders.

Commonly one sealing fan is provided for one mill, optionally one sealing fan is available for several mills（for one boiler）. Sealing air was used for sealing at grinding table carrier/pivoting bearing of tie rod /rollers. If the rotary classifier is equipped, the rotary classifier needs some sealing air.

When mill is needed for maintenance, the turning gear should be connected to mill motor tail.

3.4.4 Request of operation

3.4.4.1 General

In order to prevent dust fires and dust explosions, the relational regulation and the safety rules must be observed in operation.

The warning brand must be shown and the inlet/outlet valves of the mill must be shut during repairing, meanwhile motor is forbidden to switch on. Prevent the accident endangered lift take place!

During work at the mill, it has to be ensured that the electric valve of inert gas inlet cannot be switched on and the manual valve should be switched on.

The mill has the task to crush hard coal of one size to pulverized coal. But, foreign matters, such as metal substances, stones, blocks, and coarse foreign materials can interfere with the employ life of the mill and cause damages. Thus, those parts are not permitted in the mill. The strip and line type foreign matters cannot get into the mill that can entwine the classifier rotor, static vane baffle etc., since these not only interfere with the function of the classifier, but also cause a risk of fires by producing dust deposits. Therefore, the perfect sundries cleanup establishment should be provided to transmitting coal units.

The grinding tools – grinding rollers tyres and grinding table segments- are made of materials of high hardness and corresponding sensitivity to breakage, therefore these prevent from collision, impact and heated. For this reason, it is not permitted to operate the mill unless the mill operates at the speed of the turning gear or the grinding rollers have been put up. It is forbidden to operate the mill without material to be ground at operating speed (the grinding rollers have be loaded).

Check waste volume in the waste box during every start. Observe current consumption of the drive motor. The program protection must be provided, and operate under the alarm limited range. Pay attention to the libration capability regulation in operation.

3.4.4.1.1 The regulation of coal powder size

The change of coal powder size relates to the angle of the classifier blades, grinding force, supply coal quantity, hot gas quantity etc.

In case of first operation, the speed of classifier rotor and loading force just be decided temporarily, the angle of the classifier blades is 50°, for loading force to see fourth section. The best condition of operation and the most economical size of coal powder can be obtained after operating 1000 hours, which need performance experiment. This test mainly includes: regulation of the angle of the classifier blades, appropriate grinding force and proper hot air quantity.

During operating, the classifier should be inspected regularity, in order to prevent that the classifier function is to be effected from rotor wear or foreign matters getting into.

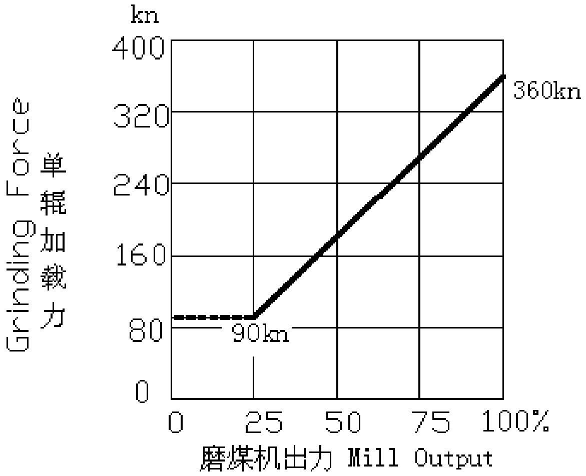
3.4.4.1.2 The loading and its speciality curve of grinding roller

The hydraulic loading is adopted in the ZGM123 mill, which can change the grinding rollers loading force by changing the pressure of the accumulator and hydraulic cylinders.

Range of throughout:　25%～100%

Force of loading : 25 %～100 % or 90kN～360kN

Pressure : 4.0 MPa～15.9MPa



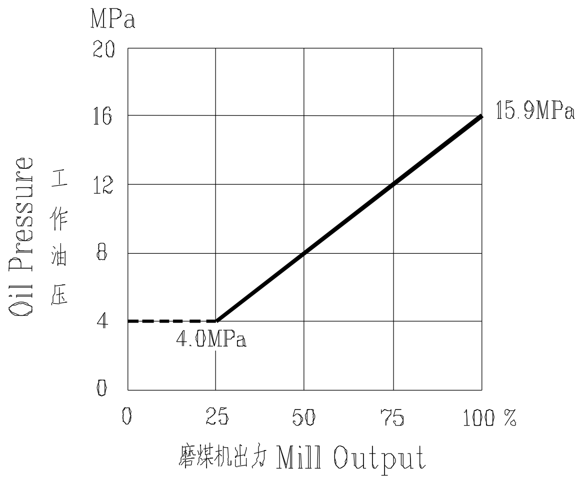


Fig.1-3 mill output-loading pressure curve Fig.1-4 mill output-oil pressure curve

The speciality curve of grinding roller:

The mill throughout (percent of coal feeder current) is regarded as x-axis of the curve, the grinding pressure and oil pressure is regarded as y-axis. The mill throughout-oil pressure curve is fig.1-3.The mill throughout-loading pressure curve is fig.1-4.The maximal loading force is 360kN, during the debugging process the maximal value can be reduced properly. For this system, since the full-load operation is economical, the best loading force should be obtained by mill performance experiments.

3.4.4.1.3 The request of the gas-coal scale

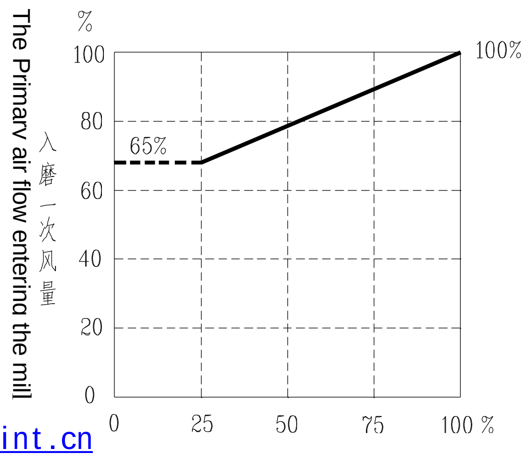


Figure1-5 "standard air curve" of mill

The quantity of supply coal and hot air may be adjusted according to the hot air -throughout curve. The quantity of hot air may be properly adjusted from standard, therefore, while *the Mill Technical Protocol* is being subscribed, the user may constitute the "standard air curve" according to the request of boiler factory and design institute, in order to insure that the hot air quantity adapt to the system. Because of the different of the throughout in the variable project, the 2 sect beeline of standard curve is different. For the material value, please refer to *the Mill Technical Protocol*.

It is very important to set up proper scale of the quantity of supply coal and hot air. Unless the quantity of supply coal and hot air is exact, not only the adjusting of load but also the operation of mill will be effected. Therefore the scale of the quantity of supply coal and hot air should be inspected according to the curve during the first operating. Then the measure equipment should be proofed regularly so as to prevent the quality trouble that measure is not exact.

Note: During the first operating, while there isn't self-regulation of the hot air quantity, at first increase the hot air, then increase the coal during increasing the throughout that be manually adjusted by the operating personal. In order to prevent the adjustment is too fast or the waste material is too much and even the coals is jammed, must decrease the coal at first, then hot air during decreasing the throughout.

3.4.4.1.4 Manually waste

Empty waste box periodically after the hydraulic gate valve has been closed. The interval depends on condition of operation. At first operating, check waste box every other half-hour. During the mill open/stop every time, must to check and empty waste box. Empty waste box every 1~2 hours in normal operation.

The waste volume should be very small, but it will increase the following condition:

①Mill startup

②Mill emergency shut-down

③Material to be ground is poor

④The grinding rollers, segments and nozzle ring have been badly worn during operating evening.

⑤The increase of mill throughout is overly rapid in operation, and the hot air volume is less than requested value.

The waste increase for mill emergent shut and startup is natural. When the increasing of nozzle wears, the wear parts must be changed in time.

3.4.4.2 The sealing request

3.4.4.2.1 The pressure of mill inner and outside is different. In order to prevent that the outside coal powder enter into inner oil space, the sealing system is provided that mainly seals the grinding rollers, base, tie rod and rotary classifier etc. Sealing request of every part:

1. Static and dynamic classifier seal: it is about 45 percent of total sealing air which is used for avoiding that coal powder enter into the oil box of classifier drive via the rotary clearance between static parts and dynamic parts.
2. Seal of grinding rollers: in order to prevent that the flying coal powder influent the rotary shaft seals, the sealing air should be kept period of time after mill shut-down, besides the normal sealing air in operation. Continuance time can be seen in the process request of mill startup/shutdown; the quantity of sealing air is about 50 percent of total sealing air.
3. Tie rod seal: It is used for preventing that powder deposit on the clearance between joint bearing and sealing ring, which is about 5 percent of total.

3.4.4.2.2 Technical data of ZGM113 mill sealing system

① Differential pressure sealing air/mill air in mill startup >2kPa

② Differential pressure sealing air/mill air in operation ≥ 1.5kPa

3.4.5 Start-up and putting out operation

The following several operating are lodged in *Logic Diagram of Start and Putting Out Operation for ZGM Mill*.

◆Mill start-up

◆Normally putting out operation

◆Shut-down

◆Emergency shut-down

3.4.5.1 The sequence of start-up (the following is reference data on

lubrication system)

1) Lubrication system startup

The lubrication system should be put into operation before mill startup. When the oil temperature is <25℃, the low speed pump should be started, then open the electric heater. When the temperature exceeds 28℃, the pump should be switched to high speed. When the temperature exceeds 30℃, the heater should be shut. As the pressure of supply oil exceeds the sum of the value of switching and 0.13Mpa, and the temperature of the gearbox oil reach 28℃, the oil temperature of thrust bearing space is <50℃, it is indicated that startup of the lubrication system has completed. The upper process is to be automatically completed by the controller of oil system.

2) Prior to startup, the following should be prepared.

a. mill inlet door closed
b. mill cold air door closed
c. sealing air valve of coal feeder opened
d. coal scuttle valve opened
e. isolation valve on mill outlet opened
f. hot air pressure achieved
g. turning gear come away
h. the pressure of hydraulic plant adjusted
i. the operation of lubrication and hydraulic plant in order
j. the system of control in order

3) Pressure of sealing air

Start the sealing fan to make the pressure difference of sealing air and hot air achieves the value that is required for mill startup ($\Delta P \geq 2kPa$).

4) Start hydraulic unit oil pump

Start pump and adjust proportional overflow valve.

5) Inert gas

Because of the accumulated coal on the grinding table, in order to prevent exploding, the inert gas should be plunged into mill for 6~10minutes before putting in the hot air.

6) Hot air

The hot air is switched on in order to clean the mill, afterwards, the quantity of hot air should be adjusted to the lowest value that mill requires.

7) Temperature of temperature of mill outlet is switched on in order to start mill

8) Mill startup condition is ok.

9) Coal feeder startup

After mill startup for 10 minutes, set coal feeder to min. volume flow, then startup.

10) The mill throughout is adjusted to normal.

11) The temperature of mill outlet adjusted

12) The proportion of air and coal adjusted

The mill throughout is adjusted based on the boiler load, which is linearly correlated with the hot air quantity that can be adjusted according to the category of coal. The every operating must be according with the automatic process, then “mill startup” will be completed. In peculiar, the manual operating can be carried out according to *Logic Diagram of Start and Putting Out Operation for ZGM Mill*. The manual buttons should be pressed after the every control process is affirmed until the mill is started (motor startup).

3.4.5.2 Putting out of operation

1) Prior to putting out of operation, set coal feeder to minimum volume flow, and at the same time reduce classifier outlet temperature based on the putting out of mill process of Logic Diagram of Start and Putting Out Operation for ZGM Mill.

2) As classifier outlet temperature ≤60℃, switch off coal feeder, uplift the grinding rollers, the mill should be putted out of operation after 60~120 minutes operation, then the grinding rollers descend.

3.4.5.3 Shut-down and emergency shut-down

Eliminate failures of mill or correlative system in time, if this is impossible, stop mill normally or by ‘emergency’.

3.4.5.3.1 Shut-down

The shut-down is performed according to the shut-down process of *Logic Diagram of Start and Putting Out Operation for ZGM Mill.*

Further criteria for shut-down include:

a. coal feeder stop or below min. volume flow
b. suddenly librates
c. lubrication units failures
d. different pressure of sealing air and hot air ≤1.5kPa

e. hot air quantity below minimum volume

f. classifier outlet temperature: $t_2 \leq 60$℃ or $t_2 \geq 100$℃（or according to project actual condition）

g. grinding rollers oil temperature ≥110℃

h. gearbox inlet oil pressure ≤1.0 kPa

i. thrust bearing oil space temperature ≥70℃

j. motor winding temperature ≥130℃

3.4.5.3.2 Emergency shut-down

The emergency shut-down is performed according to the emergency shut-down process of *Logic Diagram of Start and Putting Out Operation for ZGM Mill*.

1) Further criteria for emergency shut-down include:

- system protection action
- hot air quantity below the 85% of min. volume
- classifier outlet temperature: $t_2 \leq 55$℃ or $t_2 \geq 100$℃（or according to project actual condition）
- grinding rollers oil temperature ≥120℃

e. motor stop

2) The following equipment should be operated as emergency shut-down

- mill inlet damper emergency shut
- hot air damper and cold air ‘closed’
- coal feeder power supply switch off
- inert gases plunged into mill

3) If the failures cannot be eliminated after 1 hour emergency shut-down, the following operation should be done:

- Mill is operated non-loading in order to remove coal and prevent coal self-igniting.
- The sealing fan, lubrication units and hydraulic unit ‘closed’

4) If the failures have been eliminated after emergency shut-down, mill operation can be carried out again. The following should be done.

- Inspect mill and assistant equipment.
- Waste
- Then mill operation normally can be carried out.
- Lubrication system startup

3.4.6 Technical data for operation, protect program and alarm

3.4.6.1 Technical data for mill startup

Different pressure of sealing air and hot air:	≥2kPa
Grinding rollers oil temperature:	≤100℃
Classifier outlet temperature:	70～100℃
Temperature of gearbox oil bath:	≥28℃
Thrust bearing oil space temperature:	≤50℃
Gearbox inlet oil pressure:	≥0.13 Mpa

3.4.6.2 Technical data for mill shut-down

Grinding rollers oil temperature:	≥110℃
Coal feeder volume flow:	≤20%
Gearbox inlet oil pressure:	≤0.10 Mpa
Classifier outlet temperature:	≥100℃ (or according to project actual condition）
Classifier outlet temperature:	≤60℃
Thrust bearing oil space temperature:	≥70℃
Motor bearing temperature:	≥90℃
Motor winding temperature	≥130℃

3.4.6.3 Technical data for emergency shut-down

Classifier outlet temperature:	≥105℃ (or according to project actual condition)
Classifier outlet temperature:	≤55℃
Grinding rollers oil temperature	≥120℃

Hot air volume below 85% of the min. volume

3.4.7 Faults and remedy

During startup/shut-down, for operating and maintenance of the ZGM mill, it is required to observe the relational regulation, and it is forbidden that any equipment relating to control and alarm are shut off, wrong connected or stopped.

The following table contains the most frequent faults and provides information on how to remedy them.

o	Faults	Possible reason	Prevision and remedy
1	Abnormal operation	There are foreign matters between grinding parts. No coal or little coal in mill. The guiding board wear or interval too large Grinding parts damaged. Nitrogen quantity too small or gasbag damaged in accumulator	Shut-down, remove the foreign matters, inspect if the parts drop off in the mill. (Caution! When the iron block and rigidly matters etc. get into mill, should eliminate it otherwise the grinding parts will be damaged.) The pipe for transmitting coal may be jammed. Replace it or adjust interval; Replace; Mill Shut-down and hydraulic plan, blow or inspect accumulator.
2	The different pressure of hot air and sealing air decrease	The filter on the sealing fan inlet is dammed. The location of non return valve on sealing pipeline is wrong. The sealing pipeline leak or damage. The sealing parts are invalid.	Mill Shut-down, clean the filter. Regulate it to correct location. Repair or replace. Eliminate faults.
3	Grinding rollers cover break.	The intensively vibration in operation. The casing examine	Eliminate the source of vibration.

		door is opened too early after putting out of operation, cold air get into.	Prevent grinding rollers from the influence of largely different temperature. Replace grinding rollers cover.
4	In operation: the temperature of classifier is too low or too high. The temperature increasing too fast.	Faults of control equipment for hot air temperature Failure of hot air control Fire of the internal mill Temperature of classifier exceeds 110℃	Transform the hot air Control to manual work and eliminate the faults. As above; Emergency shut-down, the inert gas valve has been switch on until the temperature is reduced.
5	Lower oil level of grinding rollers	Sealing parts failure	Shut-down, repair or replace sealing parts, fill oil until reaching the regular level.
6	Higher temperature of grinding rollers	Lower oil lever Bearing failures Grinding rollers sealing air pipeline failures or wear	See no. 5. Shut-down, replace the grinding rollers bearing. Repair or replace.
7	Shutter break off	Bolts break off.	Retighten or replace.
8	Overabundance for Waste volume flow	Emergency shut-down or initial startup of mill. Coal quality is too poor. Grinding rollers, segment and nozzle have been worn badly.	Waste increasing belongs to normal condition in startup and shut-down. Replace the nozzle in time as the waste increasing for nozzle ring wear.

		The increasing of throughout is too fast in operation. Too small hot air volume	Adjust hot air volume.
9	Door of waste box don't sealed	Seal is mangled or there is eyewinker	Fix seal and repeat it
10	Hot air is giveaway from bottom housing	sealing air volume is lack seal was fret	Check Sealing fan Replace seal
11	Thrust tile oil temperature is high	Oil isn't enough Cooler is trouble	Check bumb and pipe
12	Thrust tile is damaged	Mill start Frequently Thrust tile oil temperature is high	Replace it and check gear box
13	Gearbox abnormity		See the gearbox instruction.
14	Lubrication plant abnormity		See the lubrication plant instruction.

3.4.8 Notices for mill operation

1) Mill outlet temperature is below rated value: coal and pulverized coal can not be fully dried due to low outlet temperature. Pulverized coal sticks on tubes and in the mill, which may cause blockage of pulverized coal tube as well as ignition of mill and tubes.

2) Mill outlet temperature is above the rated value: because pulverized coal is driven out due to outlet high temperature, risk of ignition will be increased. If mill outlet temperature rises up and surpasses the rated value, hot air intercept valve shall be

closed by control system. Mill outlet rated temperature is varied with coal type.

3) Low ventilation in the mill: low ventilation will result in pulverized coal deposition due to low transportation speed. In this case, pulverized coal tube will get stuck and then ignition may happen.

4) High ventilation in mill: this is a worse working condition. High ventilation may aggregate the abrasion of pulverized coal tubes and inner part of the mill, and affect pulverized coal fineness.

5) Too much stone coal: it is a dangerous working condition since stone coal may cause outlet and primary air inlet blockage and damage the scraper if too much stone coal can not be discharged from the side proper timely. Deposited stone will be claimed for mill ventilation blockage and ignition.

6) Inappropriate mill shut-down and cooling: insufficient purge and cooling during mill shut-down will increase the possibility of ignition at mill or coal duct.

7) Inappropriate pulverized coal fineness: too tiny pulverized coal may result in drop of mill output and increment of energy consumption. Big size pulverized coal will affect the ignition of pulverized coal and increase over fired time. Therefore loss caused by incomplete combustion will be increased.

8）Mill operation working conditions will be considerably affected by impurities mixed in raw coal. Therefore impurities shall be removed.

Chapter 4 Air-smoke System

4.1 General Introduction

4.1.1 Brief Introduction

Boiler air-smoke system is an important auxiliary system of the boiler. It will consistently supply air to the boiler for combustion and distribute air flow according to combustion request; meanwhile, it makes it possible for the dust content gas created by combustion to timely exhaust to the air through chimney after passing through every heating surface and flue gas cleaner.

Air-smoke system of boiler is designed according to balanced draft; the equilibrium point is located inside the furnace, so it is equipped with two moving blade adjustable axial-flow FD fans, two stationary blade adjustable axial ID fans, two moving blade adjustable axial-flow PA fans and two sealed booster fans. While the system is running, the air is forced into the furnace under positive pressure and the flue gas is vented out of the furnace under negative pressure. Balanced draft can ensure that there won't be too much leaking air in both furnace and air duct and high economical efficiency of boiler, prevent hot gas escape from furnace, and this is good for both the safety of operators and boiler room environment.

Air-smoke System draws flue gas out of the furnace, through tail-heating surface, air preheaters, ash separators, FD fans, high pressure fans and desulphurization units, finally exhaust from chimneys into the air. In order to balance flue gas pressure at the head and the back of ash separator and distribute flue gas equally, two ash separators are parallel connected. To prevent flue gas from return flowing into ID fans, there will be a sealed smoke damper at the exit.

Air-smoke system consists of the following facilities and sets, and the operational parameter of the system is determined by these components:

1) Two movingbladeadjustedaxial-flowFD fan

2) Two movingbladeadjustedaxial-flow

3) Two stationarybladeadjustableaxialID fan

4) Two trisector rotary regenerative air preheater;

5) Two ESP;

6) Two flameimage cooling fans;

7) Two sealing air fans;

8) Six opposed firing burners and air boxes;

9) Connect air duct, flapper or lock gate.

Air-smoke system actually are two parallel air supplying systems which sharing the same furnace, heating surface smoke duct and two ID fans. The air which is sent to furnace plays the following roles:

1) Provide secondary air for combustion by FD fan.

2) Provide primary air for convey and dry powder coal by PA fan.

3) Provide flame image detector cooling air by flame image cooling fans draw directly from atmosphere.

4) Provide sealing air for coal mine machines, mill and coal powder duct by PA fan exit through seal air fan after being boosting.

Whether sealing air or cooling air, they are both part of air required by combustion and will finally enter the furnace.

This chapter will only introduce primary and secondary air system, flew gas system and sealing air system. Other parts such as cooling air and fire detecting will be introduced in the relative chapters.

4.1.2 Secondary Air System

Send air into furnace so that fuel could burn normally in the furnace; use FD fan against flow resistance of air side air heater, gas side air heater, air duct and burner, at the same time provide oxygen for fuel to combustion.

Secondary air flow: plant ambient air enters two axial-flow FDF directly through the muffler, after being compressed by FD fans, air will be sent into air heater through cold secondary air duct, and sub-depoted by air heater separately, heated secondary air will be sent into air box and burner through heated secondary air duct and finally into furnace.

Every boiler has two sets of secondary air systems. There is connective air duct on cold air duct between FD fan and air heater, and there is motorized isolation air damper on the duct. Burner air boxes are located on the front and rear wall, and each wall have two layers of bellows. OFA bellows are located in the upper layer; secondary air is connected with each bellow from both sides of boiler. While one FD fan is breakdown, this kind of connection can make sure air preheater on both side of the boiler could still provide air to furnace so that heat deviation could be reduced and guaranteed the stability of combustion and temperature of furnace is evenly distributed.

Oil burner which is used for boiler ignition and stable combustion at low load is located inside of secondary air nozzle, thus it is designed with a separate cenrtal air access.

Before secondary air is sent into boiler bellow (main duct 1985×1985×5, 12ducts in total; Overfire ducts 1585×1585×5, 4ducts in total), there are Verabar flow rate measuring apparatus and electric control valves on each branch ducts.

4.1.3 Primary air system

Primary air system mainly used for conveys and dry powder coal and provide air for early combustion of fuel. PA fans provide primary air for mill and provide sealing

air for mill and coal feeder. Fans are moving blade adjusted axial-flow type. Every boiler are equipped with two sets of primary air system, every PA fan exits are equipped with motorized isolation air damper. There is connective air duct on cold air duct between PA fans and air heater (2200×1500×4), and there is a motorized isolation air damper on connective air duct.

After being sent into air preheater, heated primary air is brought into 2600×1800×4 connective main duct through φ2420×4 ducts on the both side of boiler and then heated primary air will be distributed to every mills. Air preheater primary air exit is equipped with motorized isolation air damper, when there is functional failure on air preheater, the correspondence air damper should be closed. Flow-metering device which is located on φ2420×4 air ducts on both sides of boiler is used to measure the total flow rate of primary heated air.

Cold primary air, come from PA fan exit, as tempering-air and sealing air, come to ϕ1520×4 connective main ducts beside the boiler, tempering-air is distributed to mix with heated primary air at the entrance of every mills. Adjust the temperature of mixed air through electric temperature control air damper on the cold and heated primary air ducts of every mill’s entrance, and make sure its temperature meet the needs of gas-solid mixture at the mill's exit. Mixed air is controlled by electric control damper. The air volume should meet the needs of flow velocity of dry and convey coal powder ducts of mills. (It shall not be less than 18m/s so as to prevent from coal deposits.)

When an emergency shutdown is occurred in mill, primary heated pneumatic damper should be closed immediately. In order to prevent the possibility of cold primary air from return flowing to heated primary air after mill is closed, there will be an electrical close isolation damper on the cold air sub-ducts. Close correspondence damper when mill is shutdown.

There will be flow-metering devices on the mixed air ducts (1500×1200×4) at the entrance of mill.

4.1.4 Sealing Air System

The sealing air system of mill has two sets of supercharged centrifugal sealing air fan, and every fan's capacity is 100%, one primary mill and one single standby mill. Sealing air of mill extracted from cold primary air connective main duct to mill through sealing air fan after being compressed. There is a filter gauge and an electric control valve at sealing air fan's entrance. When one sealing air fan is working, control valve of the other fan should be closed. Dust-laden exhaust gas comes out of filter of the entrance is connected to the heated secondary air duct of B side air preheater's exit. Two sealing air fans' exits have automatic communicating dampers, and every sealing air duct (ϕ325×5) has adjustable electro-closing-gate.

Sealing air main duct of coal feeder comes directly out of cold primary air connective main duct, and every sealing air sub-duct of coal feeder has a electric closing-gate and a hand control closing-gate. By using hand control closing-gate to control the air volume of sealing air can prevent heated air and coal inside the mill to return efficiently, and those coals on proofed cloth won't be blow off. This ensures that primary air and coal powder won't get out of the mill.

According to the factory, air volume of sealing air of every mill is 1.5 kg/s, and air volume of sealing air of every coal feeder is 10Nm3/min.

4. 1. 5 Fuel Gas System

Flue Gas System can exhaust flue gas which is created by fuel combustion into atmosphere consistently and timely after heat transfer with heating surface so that boiler could run without trouble.

Flue Gas System mainly is composed of two stationary blade adjustable axial ID fans, two air preheaters and two electronic ash separators. Boiler introduces balanced draft, furnace maintains certain negative pressure. Negative pressure is brought about by adjusting the angle of stationary blade of ID fan and changing flow rate of fans.

Input pressure of ID fan is related to boiler's load and flow resistance. Its flow rate is determined by the capacity of furnace combustion products and the quantity of air leaked from furnace exit.

Flue gas come out of the economizer exit enters air preheater in two diverges, and there will be an electronic isolation air damper. This valve will close flue gas when emergency occurs. It will be open/close when air preheater is open or closed. The rear flue gas of air preheater enter into two double-chamber five electric field in four diverges, after being dedusting (dust collecting efficiency $\eta \geq 99.8\%$), flue gas will be extracted out through two ID fans and be poured into the air through chimney.

Both ID fans' entrances and exits have electronic isolation air dampers. Air damper will cut off flue gas when emergency occurs to a fan and need to be repaired, and damper can also open/close ID fan.

4.2 Axial flow fan

4.2.1 The working principle for axial flow fans

Fluid flows into blade channel axially, when impeller is whirling by the forces of electric machine, whirling blade will provide impulse for fluid axially (when fluid is streaming around the blade, according to hydromechanics, fluid has a lift force to blade, at the same time, according to theory "acting force is equal to reacting force", blade will provide a force to fluid which is equal to lift force in magnitude but in opposite direction, i.e. impulse), work is done on fluid by blade, this increased the energy of fluid and exhausted axially. Continuous whirling of blade will generate continuous work of axial flow fan.

Assumed that a relatively long cylinder is motionless, air flow paralleled flow from right to left, gas viscosity is neglected (resistance of gas flow), then air flow will evenly streaming around the cylinder in two ways. The speed and pressure of air flow distributed full symmetry on cylinder, total acting force is 0, as FIG 5－1. This kind of flow is called advection flow around cylinder fluxion.

If cylinder whirls clockwise, the gas around it whirl too, that produces circulatorymotion. Then the speed and pressure above and under the cylinder are full symmetry too, total acting force is 0, as FIG 5－2. This is called circulatorymotion.

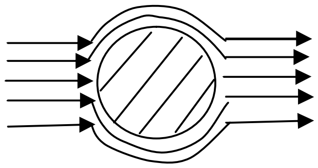


FIG 5-1

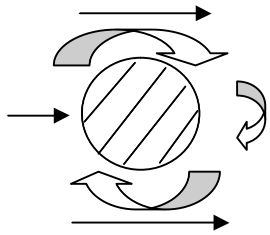


FIG 5-2

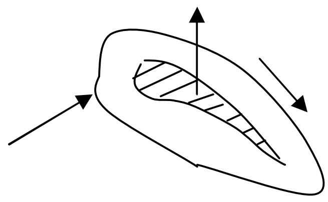


FIG 5-3

FIG 5-1 Advection flow around cylinder fluxion

FIG 5-2 Circulatorymotion

FIG 5-3 Theory of airfoil lift force

If fluid acting parallel and cylinder whirl clockwise, then: fluid above the cylinder flow the same direction with circumfluence, flow velocity is speeded up; fluid under the cylinder flows the opposite direction with circumfluence, flow velocity is slow down. According to theory of energy equation, total energy of upside and underneath of cylinder are equal, and kinetic energy of upside of cylinder is greater, pressure is light; kinetic energy of underneath of cylinder is smaller, pressure is heavy. Then fluid produces pressure difference on cylinder bottom up, this pressure difference is called lift force.

The theory of airfoil lift force enjoys the same theory of cylinder lift force. As shown in FIG 5-3, there is a clockwise circulatorymotion upside the airfoil, because airfoil moves ahead, so airfoil is doing advection movement for fluid. Advectional flow and circular flow upside the airfoil superimposes together and the speed become faster, pressure is decreased, advectional flow and circular flow under the airfoil superimposes together and the speed is slowing down and pressure is increased. Then produces a lift force P. There is a flow resistance during flowing process and airfoil received a resistance.

Impeller of axial flow fan consists of several airfoils in the same type; it is an

O-ring cascade, as FIG 5-4. If expand impeller at the same radius, as FIG 5-4, when impeller is whirling, cascade will move forward at the rate of U, for cascade, air flow move against surface of airfoil, airfoil received a lifting force P, and airfoil provide a reacting force R to fluid, force R could be decomposed into Rm and Ru, force Rm prove power for fluid to flow axially, force Ru make gas whirling, so gas move axially around axis after blade apply work to it.

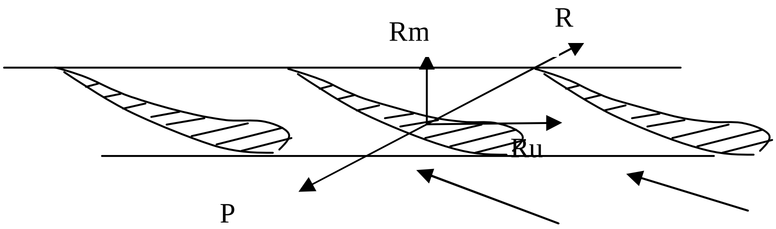


FIG 5-4 Analyze figure of interaction between airfoil and fluid in O-ring cascade

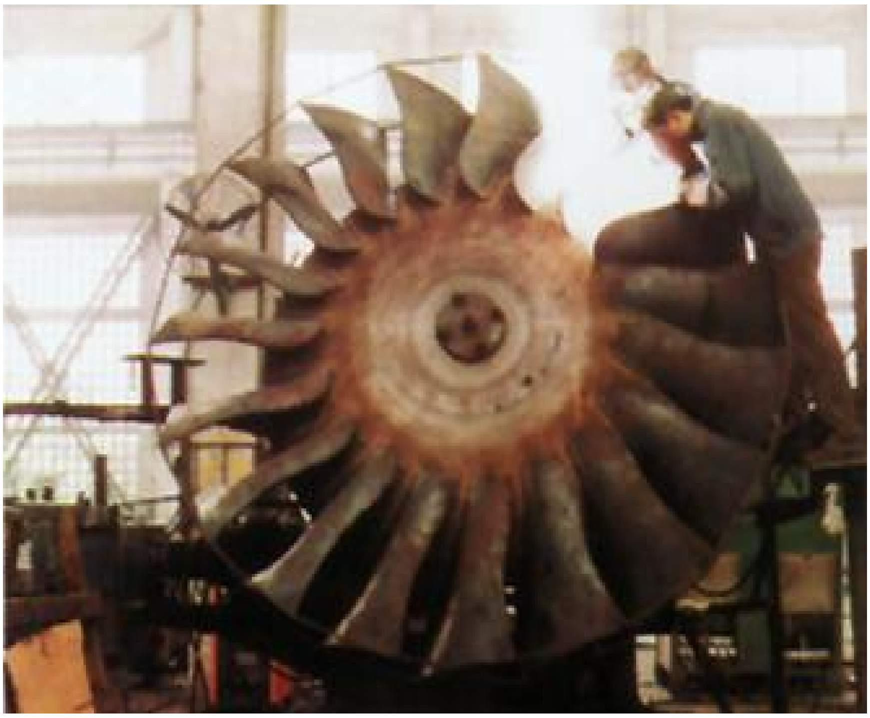


FIG 5-5 Blade of axial flow fan

4.3 Stall and Surging of Fan

4.3.1 Stall

According to hydromechanics, when v-speed advection streaming around

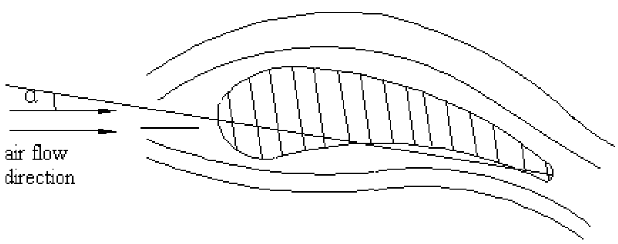
binary isolated airfoil in a attack angle (angular separation between wing chord and the direction of incoming flow), because the dissymmetry of the both sides of air flow, streamline in upper area of airfoil become close, flow speed increased, and streamline in lower area of airfoil become sparse, flow velocity decreased. So the pressure on lower surface of airfoil applied by fluid will greater than that on airfoil upper surface, and then form an upward force on the airfoil. If hydrodynamic form is perfect fluid, then the force which is vertical with inflow is called lifting force, how heavy or slight of this force is determined by Joukowski Function:

$$FL = \rho \upsilon_\infty \Gamma$$

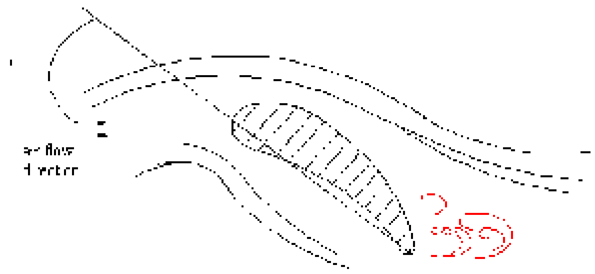
Γ—velocity circulation ρ—density of streaming fluid

The direction of lifting force is determined by the direction of inflow velocity shift 90° on the opposite direction of velocity circulation.

In the same circumstances, the value of pressure difference between both sides of axial flow fan's blade is determined by the value of attack angle of rotor blade. Within the value of critical attack angle, the pressure difference mentioned above in proportion to attack angle of blade and different blade has different value of critical attack angle. If attack angle of airfoil overthiscriticalvalueboundary-layer separation phenomena and large eddy, then total pressure of fan decreased, this is called "stall phenomenon". As FIG 5—13.



a. Air flow in normal condition of fan



b. Air flow in stall condition of fan

FIG 5-14 Air flow in normal condition and stall condition of fan

When pump and fan is in unstable condition, its blade will suffer rotary separation, this may bring about resonant vibration and fatigue failure on blade. We'll take axial flow fan as an example to explain rotary stall and its resonant vibration. When fan is in the normal condition, attack angle to be 0, air flow around airfoil remain streamline, as figure: When air flow forms positive attack angle with attack anglerear edgerotary seperationstall stall occurs inside of blade

Because of the process of fabrication and installation, it is impossible for fan blade has completely same shape and established angle, and direction of incoming fluid is uneven. Thus, when operating condition is change and direction of fluid is deviate, attack angle of every blade entrance couldn't be completely same, if one blade entrance reaches critical attack angle value, stall will occur on this blade rather than simultaneous stall on all blades. As FIG 5-15: If airflow obstruction begin with blade passage 2 because of stall, flow that passing through passage 2 will decrease, low speed stagnation zone will form in this passage, then fluid which should enter into passage 2 will be distributed into two distributaries and flow into passage 1 and 3 separately. The two distributaries will converge with incoming fluid which should enter into passage 1 and 3, and this could change the direction of fluid which should enter into passage 1 and 3, the attack angle of fluid in passage 1 will be reduced and that of fluid in passage 3 will increase. The result of distribution will reduce the possibility of stall in passage 1, even disappear; but the enlargement of attack angle will lead to stall in passage 3, and this will block passage 3, and so on, stall will move along the

opposite direction of impeller. Experiment tells that relative speed of stall spreading W1 is dramatically smaller than rotary velocity of fan W, so in absolute movement, stall zone is moving at the speed of W-W1 and at the same direction of impeller.

When fan is in unstable condition, one or several rotary separation zones will occur in impeller, blades going through these zones in sequence will suffer alternating stress, and this stress will fatigue blades. Every time when blades go through these zones, blades will suffer from exciting force, the frequency of this force varies directly with the speed of rotary separatable condition.

FIG 5-15 shows Q－H performance curve of axial flow fan, at the left side of the peak point of total pressure, there is an unstable zone, and it is the rotary separation zone. Rotary separation begins with the peak point and moving to small-flow zone, and there always exists stall between the beginning and zero flow rate.

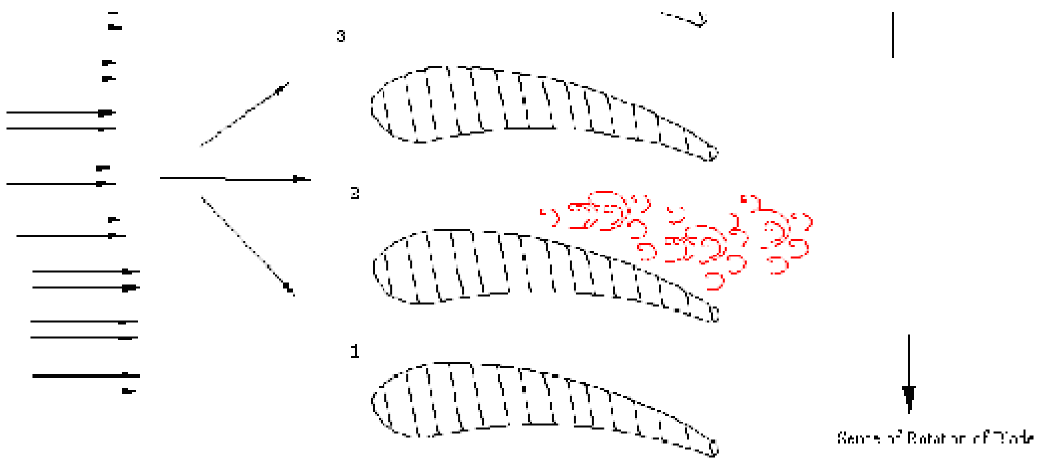


FIG 5－15　　Formation of rotary separation in moving blade

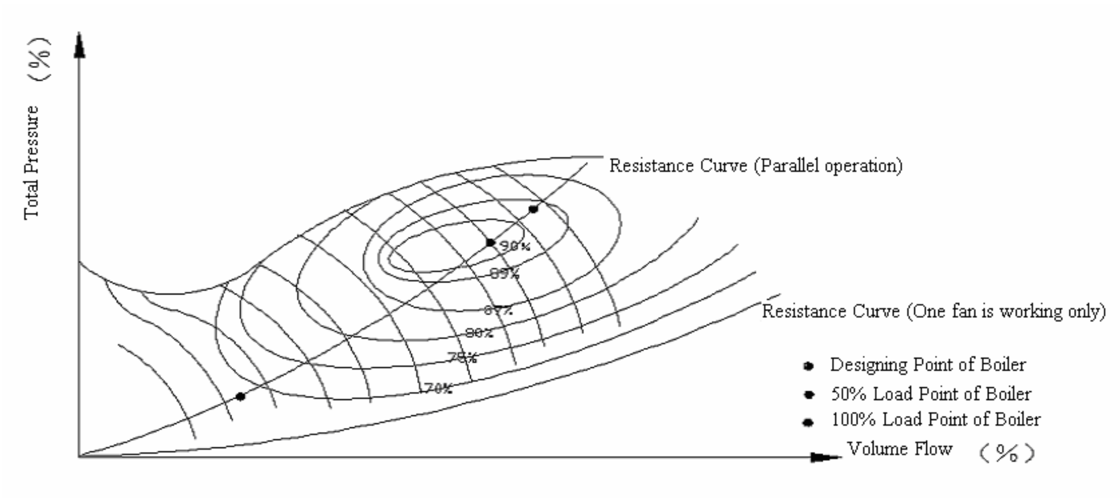


FIG 5－16　Q－H performance curve of axial flow fan

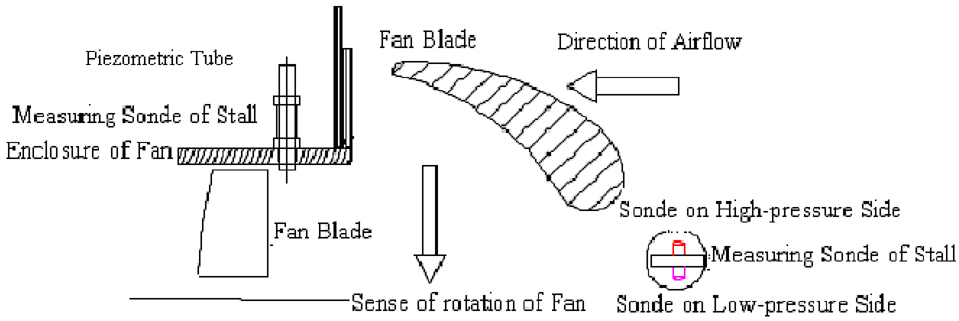


FIG 5-17 Diagrammatic sketch: Installation position of stall probe of axial flow fan

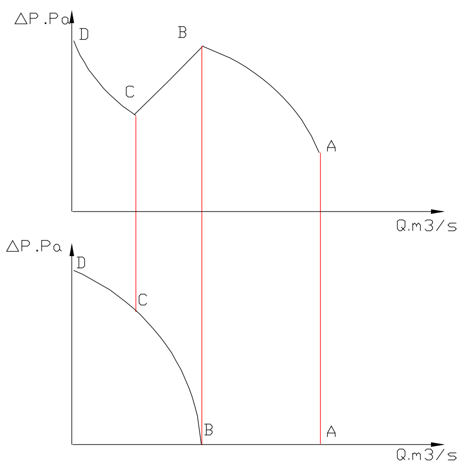


FIG 5－18　　Performance of stall probe of axial flow fan

Influence of rotary separation on fan maybe not so remarkable. Although

airflow in rotary separation zone is unstable, flow rate, pressure and power of fan is all basically stable, fan can still run under rotary separation situation. So if working point of fan is in stall zone, it is difficult for operating stuff to judge by feeling.

Because rotary stall is not so easy for operating staff to discover, and fan in stall zone is dangerous for itself, so normally there will be stall probe on large capacity axial flow fan so that operating staff could discover dangerous condition in time. As figure 5-17, stall probe consists of two piezometric tubes separated by 3mm thick and 3mm high (higher than enclosure) space and it is installed at the entrance of impeller blade. When fan is working under normal condition, airflow at the entrance of impeller will flow evenly from admission chamber along axis into fan, the pressure difference between stall probes is equal to or slightly larger than zero. In FIG 5-18, △P is pressure difference between two stall probes.

when working point of fan in rotary separation zone，besides axial flow，air flow in front of impeller will have a peripheral direction weight flow created by stall zone passage block. Thus, when impeller is whirling, pressure tap it first met, i.e. the pressure tap in front of spacer has high pressure, and the tap at the rear of spacer has low pressure, so it creates pressure difference. Normally, it will warn when the pressure difference created by stall probe reach to 245~392Pa. The smaller flow rate of fan, the larger pressure difference of stall probe, as BCD curve in FIG 5－17. When pressure difference reaches to setting value, stall probe will alarm operation staff to eliminate dangerous condition.

After stall probe is setting up, calibrate it through debugging, adjust angle of sonde’s centre line, and make sure pressure difference of pressure tube of fan is min. in normal condition.

4.3.2 Surge

Left part of performance of axial flow fan has a saddle-shaped zone, in this area there will have some abnormal conditions sometimes, such as drastically impulse on flow rate, pressure head and power of fan, strong vibration in fan and tube and remarkable

increase of noise, and so on, they are called "surge", the abnormal condition is called “surge area”. In fact, surge is phenomenon that would possibly occur in unstable condition, it is rotary separation or rotary stall that will inevitably occur in this condition. They are two different conditions and they are connected with each other.

As FIG 5—19: Q—H performance curve of axial flow fan, if reduce flow rate by throttle governing, e.g. working point of fan is on the left side of K point, then fan is in normal condition. When fan’s flow Q< QK, the maximum pressure head created by fan will decrease and it will be lower than the pressure in tube. Because capacity of air duct system is large and pressure in air duct still remains HK, so pressure in air duct is larger than pressure head which created by fan and this make air flow flows back in the opposite direction through air duct into fan, working point move quickly from K to C. Because backflow air flow decreased air volume in air duct system, so pressure of air duct will decrease rapidly and working point will decrease to D point, flow rate Q=0, along CD line, at this moment, flow rate which is supplied by fan is zero. Fan is still running, when pressure of air duct is decreased to D point, fan will supply air flow again, in order to balance with pressure of air duct, condition point will move from D to F. As long as flow rate of outside is lower than QK, the process above will repeat. If working condition of fan working as F—K—C—D—F repeatedly and this circulation has the same frequency as fan system, there goes the resonant vibration.

Fan in surge area, flow rate surge rapidly, collision which created by air flow surges fan strongly, noise is increased and air pressure changes consistently, the larger the capacity and pressure head of fan, the more the dangerous of surging. So surge condition of fan as follows:

a) working point of fan is in Q—H performance curve area;

b) air duct system, with large capacity, and fan consists a ductile ；

c) When entire circulation has the same frequency with airflow, resonant vibration occurs.

Rotary separation and stall occur in the unstable area which is at the left side of Q—H performance curve, so they are closely related.

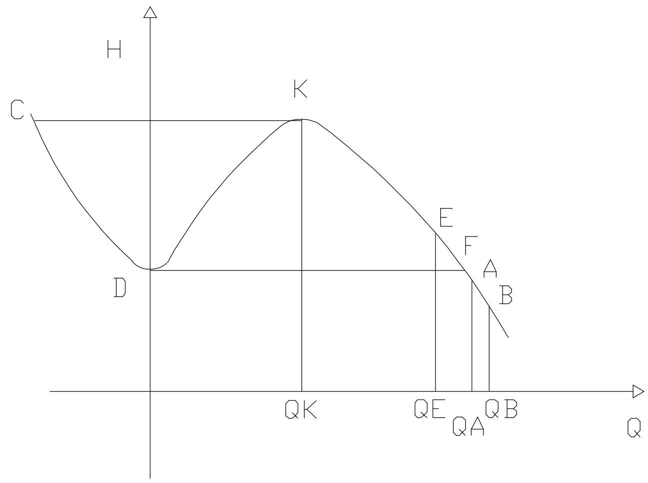


FIG 5－19　 Q－H performance curve of axial flow fan

But there is fundamental difference between rotary separation and surge. Rotary separation occurs in the entire unstable area which is at the left side of Q－H performance curve crest value of fan; Surge only occurs in the top right sloping portion of Q－H performance curve. Rotary separation is determined by factors such as structural performance of impeller blade, air flow situation, and so on, it has no connection with capacity and shape of air duct system. In normal condition, rotation does not have so badly effect as surge does on fan.

It is different condition when surge occurs on fan. When surge occurs, there will be impulse or large impulse on flow rate, total pressure and power of fan, at the same time there will be obvious noise and sometimes high pitched squeals noise. Sometimes the effect of surge is

There is surging alarm at the entrance of impeller of axial flow fan; this kind of alarm is made of a pitot tube set in front of impeller, and the opening of pitot towards the rotary direction of impeller, as FIG 5-20. A straight tube which ends to be bending in 90° (the opening of pitot towards the air flow direction) is Pitot. Connect pitot with a U-tube and reading of U-tube (pressure gauge) should be the sum of kinetic energy (dynamic pressure) and static pressure (total pressure) of air flow. In normal condition, pressure of air flow which pitot detected is negative one, because it is pressure in front of impeller. However, when fan in surging condition, because there is large range of fluctuation on pressure of air flow, so the pressure which pitot have detected is fluctuated value too. In order to make sure pitot can set alarm through pressure switch by release pulse stress, and the value of pitot is set like this: When moving blade in the position of min. angle (-30°), pressure which in front of impeller detected

by U-tube plus 2000Pa will be set point of surging alarm. When working condition surpasses surge limit, alarm will be setting out through pitot and voltage switch by light and sound towards console so that operators can deal with it, and make fan back to work in normally.

In order to prevent operating point of axial flow fan to be located in rotary stall and surge area when fan is working, operators should check whether axial flow fan work in stable area carefully, at the same time, when choosing the way of adjustment, operators should focus on variation of working point, adjust , when fan decreases flow rate and decreased air flow will slow axial speed down so that attack angle of air flow will change, and this change will be made up by the change of established angle of moving blade, therefore the attack angle of air flow could not be increased, then fan will not have rotary stall, not to mention surge. When established angle of moving blade decrease, fan's unstable area will decrease too, and this is very good for fan to work in stable condition.

Precautions of Surge:

1) Make flow rate of pump or fan large than QK. If flow rate of system smaller than QK, recirculation tube or automatic discharge valve could be installed so that out put flow rate of fan will larger than QK consistently.

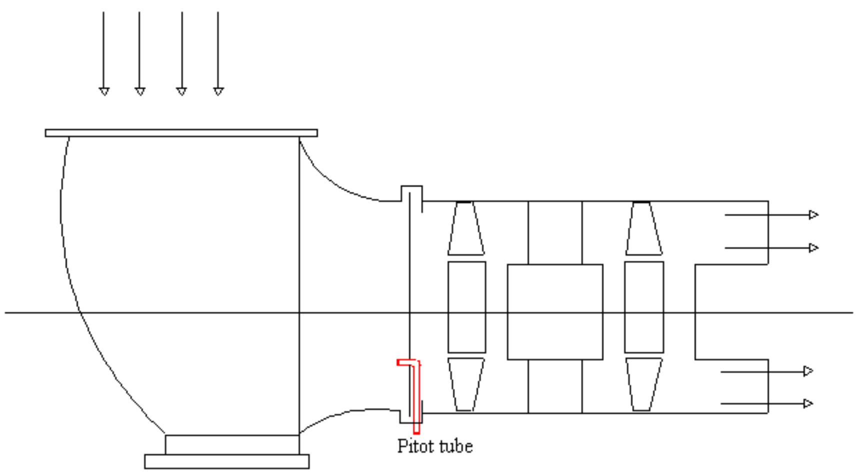


FIG 5－20　alarm device of resonant vibration

2) If tube's performance curve doesn't pass origin of coordinates, stable working condition could be obtained by changing the rotary speed of fan. Divide performance curve of fan into two parts by top pressure point of parabola in performance curve of fan at different rotary speed, stable area on the right and unstable area on the left, when performance curve of pipeline go through origin of coordinates, it will be no

effect to change rotary speed because all rotary speed are at the same working condition at origin of coordinates.

3) Axial flow fan could be adjusted through moving blade. Decrease established angle of fan when flow rate is less needed by system, performance curve will going down, and critical point will moving towards lower left and output flow rate will decrease respectively.

4) The fundamental precaution is to avoid hump-shaped performance curve fan, it is downward sloping performance curve fan that should be applied.

Stall and surge are two different concepts. Stall is a fluid power phenomenon which is created by structural character of blade. Some of its basic characters, such as rotary speed in stall area, initial point and vanishing point of stall, etc. all have their own characters and won't be influenced by capacity and shape of fan system.

Surge is a manifestation of which is created by coupling of fan's function and tube. Its basic characters such as amplitude, frequency are decided by capacity of fan's duct system, and oscillation of its flow rate and pressure resulted from unstable area. But the experiment tells that surge always is related to rotary stall in blade passage, and increase of attack angle is related to decrease of flow rate. So, rotary stall will definitely occur in unstable working condition while there is a surge condition.

4.3.3 Adjustment of axial flow fan

There are three operational adjustment of axial flow fan: variable-speed control and stationary blade adjustment.

4.3.4 FD Fan, primary fan type, parameter (introduce with disk)

4.3.4.1 Type

FD fan：ANN-2660/1400N

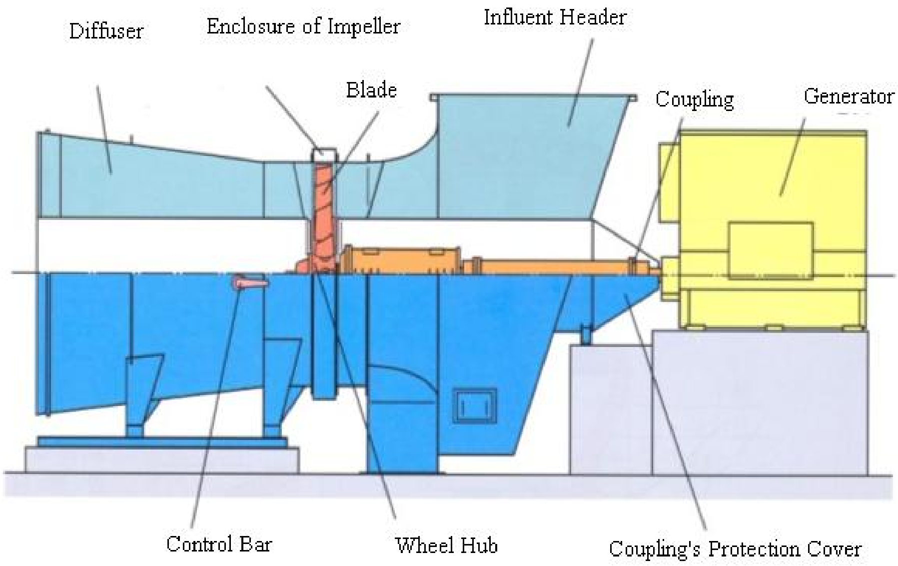


FIG 5-6 Structure of single-stage moving-blade adjustable axial FDF

PAF: moving-blade adjustable axial PAF 19-13.3-2

FIG 5-7 Structure of double stage moving-blade adjustable axial PAF

4.3.4.2 Main Structural components of the fan

The fan is sub-divided in main structural components. These are also sub-divided in sub-structural components. Consequently the most important fan components get a component No. each, which will be shown in the following in round parentheses.

The main structural component groups are:

10.00 Rotor assembly

20.00 Driving components and controlling elements

30.00 Supply units

40.00 Measuring devices

50.00 Structural steel components

60.00 Arrangement of the structural steel components

74.00 Inlet silence

77.00 Expansion joints

1) Rotor assembly (10.00)

The rotor assembly of the one-stage fan consists of an impeller (12.11) with blades (13.21), the hydraulic impeller blade adjustment system (18.00), the thrust device (19.00) and the main bearing (11.00).

2) Main bearing (11.00)

The main bearing as compact unit consists essentially of the main shaft (11.11) with the anti-friction bearings as well as the bearing housing (11.41). One is centered and screwed in the lower part of the fan housing.

For the sealing of the main shaft at the housing penetration radial shaft seal rings are provided.

On the coupling side there is the fixed bearing, consisting of one angular contact ball bearing for the absorption of the radial force and the axial thrust. On the movable bearing side a cylindrical roller bearing is arranged for the absorption of the B-side radial load.

The lubrication of the bearings is effected by oil circulation lubrication. For this very an oil supply unit is arranged outside the fan.

3) Impeller (12.11)

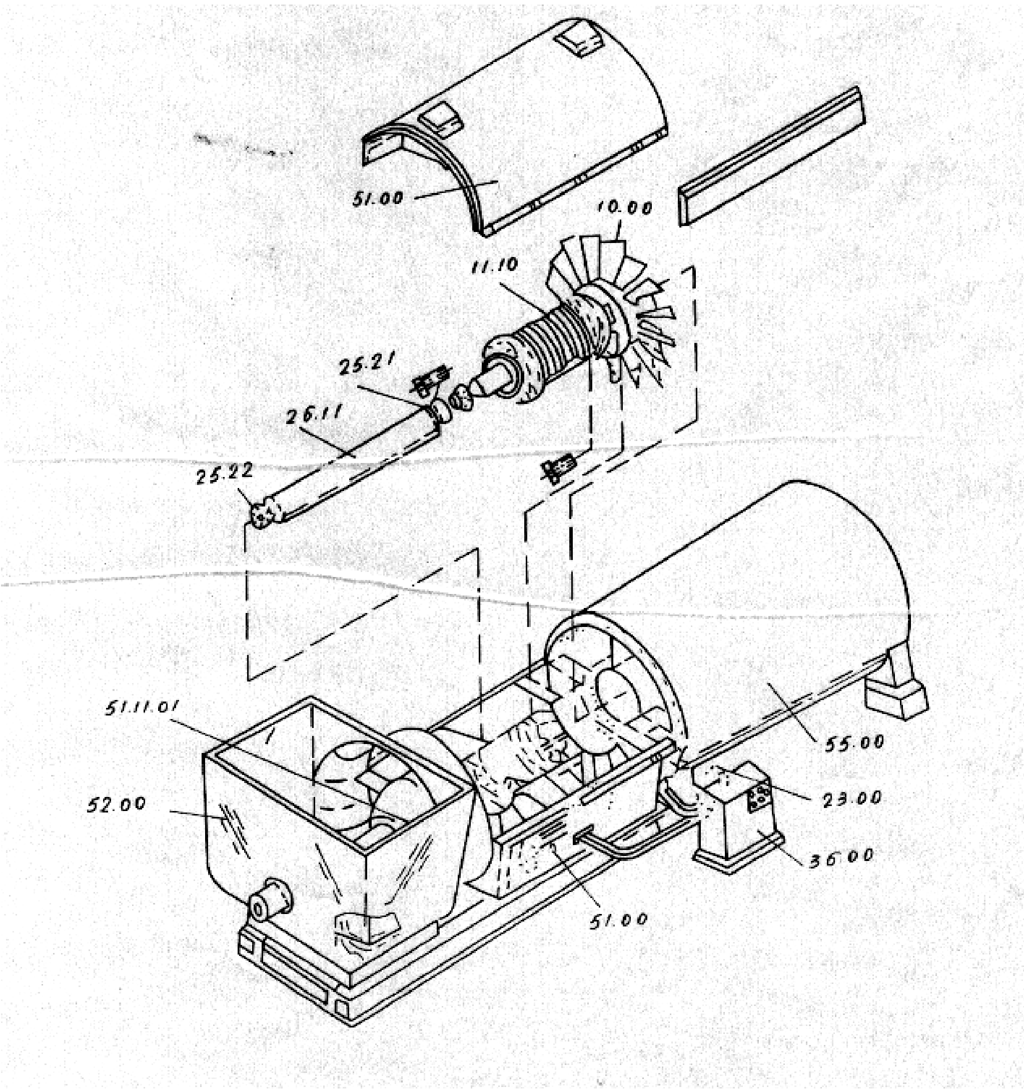
The impeller consists of welding hub, support disc, the solid girder for the absorption of the centrifugal forces, the guiding ring, the foundation disc and the impeller shell.

As connection of hub and fan shaft an interference fit with feather keys is provided. When arranging the impeller on the shaft, the welding hub will be oil hydraulically widened. The centrifugal forces of the blades (13.21) and the shafts (14.11) are transmitted via axial deep groove ball bearings into the relatively small load carrying ring, from which result a small weight and a small mass moment of inertia.

Before delivery, the complete rotor assembly will be dynamically balanced.

4) Hydraulic impeller blade adjustment system

The blades (13.21) are adjusted during operation by the hydraulic impeller blade adjustment system and kept in position. The adjustment range will be shown in the characteristic diagram and in the rotor assembly drawing.



The blades (13.21) fixed at the outer end of the shaft (14.11) are adjusted or kept in position by a lever (14.56) which is provided with a sliding block and which is arranged at the inner end of the shaft. Those sliding blocks are fit in the adjusting discs (19.32/19.33).

The adjusting discs are connected with the cylinder of the hydraulic impeller blade adjustment system (18.00).

The control of this cylinder is affected via a control slide valve in the control head.

The pressure oil in the control slide valve room can get through the bore holes setting free by the control slide valve into the respective conduits to the respective side of the adjustable cylinder, which is correspondingly movable and the blades and thrust rod are adjustable in a similar way. The oil on the other side of the cylinder can return also through the conduits back to the oil tank.

The adjusting cylinder is moved axially and due to the mechanical connection of the feed back rod with the adjusting cylinder this rod will travel axially at the same time. By these via gearwheels the control slide valve will be moved back and the oil conduits will be closed: the adjustment procedure is finished and the whole control system will be stabilized.

4.3.4.3 Design Data List

FD：

Internal diameter of the fan 2818 mm

Diameter of the impeller hub 1496 mm

Stage number 1

Number of blades per stage 14

Blade material HF-1

Connection blade/blade shaft screwed

Diameter hydraulic cylinder Ø336/H100MET

Hydraulic stroke 55°

Impeller adjustment range -30°~+25°

Gap between internal fan diameter and outer fan diameter (blades in closed position) 2.8~5.6mm

Condition	Air volume Q	Air pressure P	Dielectric density	Efficiency	Rotating speed	Shaft power	Electrical power
	m3/s	Pa	Kg/m3	%	r/min	KW	KW
T.B	324.79	5567	1.0930	82.08	985	2161	2300
BMCR	251.38	3859	1.0930	87.27		1097	
TMCR	219.99	2904	1.0930	79.36		797	

PAF：

Internal diameter of the fan 1884 mm

Diameter of the impeller hub 1334 mm

Stage number 2

Number of blades per stage 24

Blade material HF-1

Connection blade/blade shaft screwed

Diameter hydraulic cylinder Ø336/H100MET

Hydraulic stroke 505°

Impeller adjustment range -30°~+20°

Gap between internal fan diameter 1.884~3.768mm

and outer fan diameter (blades in

closed position)

Condition	Air volume Q	Air pressure P	Dielectric density	Efficiency	Rotating speed	Shaft power	Electrical power
	m^3/s	Pa	kg/m^3	%	r/min	kW	kW
T.B	130.19	16828	1.0930	83.37	1490	2485	2650
BMCR	89.66	12907	1.1755	88.15	1490	1257	2650
TMCR	82.43	11900	1.1755	88.03	1490	1070	2650

4.3.5 Operation and Maintenance of Air Fan

1) Initiation of air fan

a) Examination before initiation. Check lubricating oil system, cooling water system, hydraulic system, some protection and interlock setting, surveillance system which are related to initiation of fan.

b) Air fans could be initiated by on-site mode, remote control mode and programmed mode, but in the preliminary operation of checked fan, on-site short range remote start is normally adopted, and there will be staffs specially assigned to check the turning, raising speed and operation of fan for timely analyze and treatment under the abnormal conditions. And the current and start time of fan shall also be inspected and the air amount shall be adjusted. In the preliminary operation of fan, confirm no coal deposits in system to prevent large amount of combustible entering into furnace, to avoid furnace blasting or reburning of combustible in gas duct.

c) For guarantee the safety of FD fan and primary fan, the fan shall be started under the minimum load, i.e. the movable vane angle of fan is 0, outlet damper closed; the power of axial-flow fan will drop with the raising of air amount Q. therefore, movable vane angle is smaller, the axial power of fan will be small as the air amount becoming larger.

d) Open the movable vane gradually after the fan started, and note the surging zone. Check the operation condition of fan completely after normal start, including: the vibration of motor and mechanical part,

bearing temperature, current, air amount/pressure, motor coil and iron core temperature, movable parts and metal, operation conditions of accessories and systems (lube system, cooling water system etc).

2) Stop of fan

a) Actuating range of fan interlock shall be considered when fan in stop, and lower the loading of unit plant, open the related connection air dampers;

b) Stop the movable vane of FD fan gradually, transfer the loading of fan that need stop to another fan;

c) Close the outlet damper of FD fan;

d) Open the secondary air connection valve;

e) Stop FD fan;

f) Stop the fan oil system as required.

3) Notes for the normal condition of fan

a) In FD fan loading adjustment, loading difference for both fans shall be allowable to protect the fan working normally.

b) Switching operation of the oil cooler shall be conducted regularly. In switching, charge oil and degas for the standby oil cooler, and then open the oil outlet valve of oil cooler and the inlet, outlet valve of cooling water; when all work in normal, stop the previous running oil cooler.

c) In high pressure difference of oil system strainer, timely switch into the standby strainer operation, inform the maintainers to handle with.

d) Low oil level of any part of fan is found, oil charging shall be operated timely.

e) In normal operation, current is the mark of the fan loading, and also the forecast for abnormal circumstance. The air pressures of the inlet, outlet of fan reflect the operation condition of fan, the air leakage of boiler and the affiliated system or dust and dregs deposit condition of the heating surface, which need analyze normally and carefully. In operation, check the temperature, vibration, lube flow rate of fan and bearing of motors, voices of each system and rotating part.

4.3.6 Fault analysis and handling

Table 5-2 Common fault analysis for FD fan and PAF

Fault symptom	Fault cause	Check item

Fault symptom	Fault cause	Check item
Main bearing being overheated	1.insufficient lube flow rate 2.cooling water shortage of cooler 3.cooler adhered dirt 4.foreign matter in bearing	1. Properly adjust overflow to raise oil pressure 2. Check the cooling water quantity, and the cooling water pipe. 3.clean the inside and outside of water cooling pipe 4.check bearing, replace the ones with allophone
Low oil pressure of system	1.oil pump fault 2.unfullness of oil pump suction inlet 3.oil level in tank over low 4.overflow valve failed 5.excessive gap of the fluid cylinder valve plug or bad working condition (large oil draining)	1.check and maintenance 2.check the suction inlet 3.oil and check the leakage of pipeline 4.adjust and overhaul 5.Check the valve plug gaps and adjust fluid cylinder
high oil pressure of system	1.abnormal working condition of overflow valve 2.overflow valve outloading line clogging	1.adjust and overhaul 2.check and maintenance
Standby oil pump no action	1.electrical fault 2.vane stuck by foreign matter	1.check circuit 2.check and repair

Fault symptom	Fault cause		Check item
Abnormal noise	Host machine	1.foreign matter in fan 2.interference between rotating parts and stable parts 3.surging	1.check and repair 2.check and repair 3. Decrease the opening degree of movable vane to make the fan quit surging zone.
	Oil pump	1.air in the oil pump 2.cavitation erosion	1.exhaust air 2.clean suction inlet
Vibration	1.fan not centering 2.main bearing fault 3.rotor unbalance 4.surging 5.sealing-off of wind cone support plate or base plate		1.align fan center 2.check bearing，replace as required 3. Check abnormal wear, crack or dust adhering. Check the blot and nut connection. 4.Reduce movable vane opening degree to make the fan quit surging zone 5.overlaying wielding
Oil leakage at main bearing	1.large amount of lube 2.damage on gasket or sealing strip 3. Returning oil block of lube or air blocking.		1. Check the overflow valve above on the lube oil inlet pipe. 2.replace 3.check and repair
Movable vane stuck	1.hub inner adjusting devices damaged 2.operation mechanism stuck 3.movable vane supporting shaft		1.repair and replace 2.repair and replace 3.change lube and movable vane bearing

Fault symptom	Fault cause	Check item
	lube shortage	
movable vane angle adjustment abnormal	1. Abrasion of articulated pipe joint and valve plug, valve housing. 2. Damage of piston ring and teeth type sealing. 3.damage of flexible hose (oil leakage) 4.movable vane clamping	1.replace worn parts 2.replace 3.replace 4.as the fault handling of movable vane clamping

4.3.7 IDF

Adjustment mode of IDF adopts static vane adjustment; the type is of axial flow type, made by Chengdu Electrical Machinery Factory.

4.3.8 Mode and parameter

1) Mode：Static vane adjustable axial flow type AN33

2) Technology and performance parameter

Table 5-3　IDF technical parameter AN33

Item	unit	value
Air fan mode	**AN33**	
Air fan adjustment device mode	**A174T00**	
Impeller diameter	mm	3750
Axle material	--	35
Hub material	--	16MnR
Vane material /vane number	--/vane	16MnR/13
Static vane adjustable range	degree	-75～30
Rotor weight	kg	4500（inclusive of intermediate shaft）

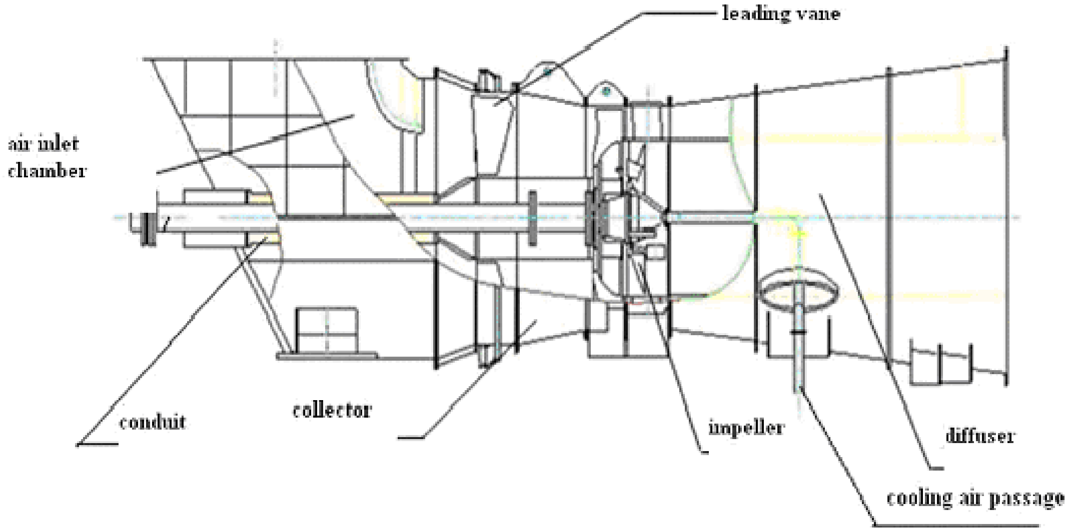
Item	unit	value
Rotor movement of inertia	$Kg.m^2$	5400
First critical rotating speed of air fan	r/min	790
Air inlet box material /wall thickness	/mm	Q235/8
Shell material /wall thickness	/mm	Q235/22
Diffuser material /wall thickness	/mm	Q235/8
Air fan bearing mode	--	Rolling bearing
Bearing mode of lubrication	--	Fat lubrication
Bearing cooling method	--	Cold air fan forced cooling
Bearing pad cooling water quantity	t/h	None
Rotation direction of air fan（see from the side of motor）	--	Negative rotation
Air fan gross weight	kg	70000
Air amount	m^3/s	539
Air pressure	KPa	4.312
Fan speed	r/min	580
Impeller series	series	1

4.3.9 Construction profile

AN air fan is of a meridian acceleration air fan, consisting of air inlet chamber, leading vane, collector, impeller, impeller rear and diffuser. (As fig 5-10) in operation, fuel gas enters into inlet chamber, with the guidance of leading vane, and speeded up in the collector, then creating static pressure power and kinetic power worked by the impeller; leading vane rear alters the screw motion of fuel gas into axial motion entering into diffuser, and changing the kinetic power of fuel gas into static pressure

power in the diffuser.

Bearing bushing is used for reducing the scouring of fuel gas for the bearing, protecting the bearing out of abrasion of high temperature fuel gas.



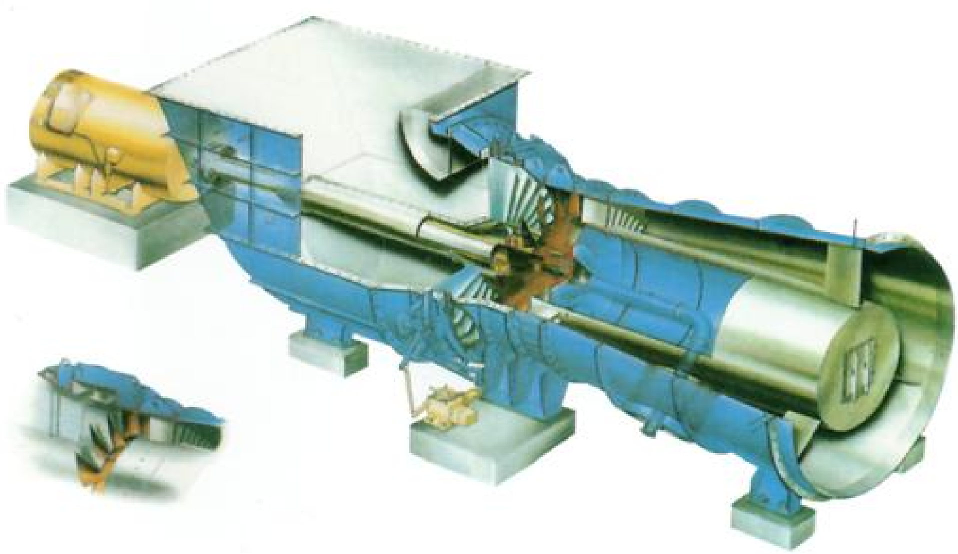
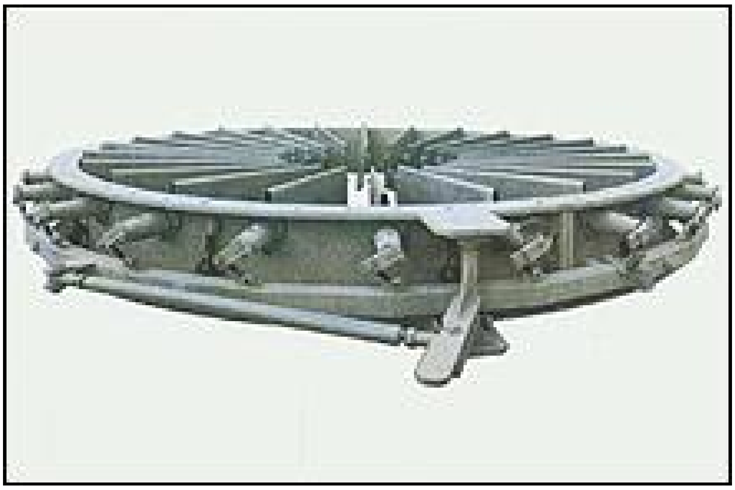


FIG 5－10　AN static vane adjustment ID fan construction

FIG 5－11　ID fan impeller

← Fig 5－12　Guide vane rear



←Fig 5－13

Leading vane adjustment device

4.3.10 Operation and maintenance

1) Before initiation of ID fan, it shall be confirmed that there is one cooling air fan under normal operation, with leading vane closed and maintained on a position of -75 degree and with inlet insulation door in close position and outlet insulation door in full open position. Rolling bearing and its inner space shall be filled with grease, grease shall be without hardening, or replace the grease.

2) In operation, inspect the main bearing temperature, make sure it below 70℃, when temperature over 90℃, send alarm, and start the other cooling air fan with interlocking, make the temperature drop below 70℃.

3) For monthly grease oiling is around 150g, and the service life of vane is over 40000 hours, one hub could stand 3-4 times vane replacing, guide vane rear can be replaced in operation, no maintenance for lubrication station, cooling water system, therefore cutting the maintenance cost.

4) For low rotating speed of ID fan, relatively stable air flow, low noise, no lubrication station, no cooling of cooling water, avoid overflowing, bleeding, dropping and leakage of lubrication, it is good for maintaining the operation condition of the power station.

4.3.11 Fault analysis and treatment

1) Large vibration of ID fan

Main reason：For the friction, dust depositing, damage, the impeller losses balance; coupler is not centered or damaged, balance losing; anchor bolt loose or mechanical joint part loose; friction between impeller and shell; bearing clearance abnormal; bearing damaged or worn.

Treatment：Switch into manual control of air fan, properly lower loading, inspect the vibration value, if it keeps on rising to the trip value, air fan will trip automatically,

or shutdown the machine manually.

2) High temperature of bearing

Reason: Large vibration, incorrect installation, damage, excessive lubrication, lubrication shortage or degenerated lubrication quality, insufficient cooling water or high cooling water temperature of bearing.

Treatment：For the problem of bearing itself, stop to handle, for the insufficient cooling water flow, make some adjustments. Adjust oil level or replace oil; and it will trip automatically, if it keeps on reaching to the trip value; otherwise shutdown the machine manually.

Chapter 5 Air PH

The model LAP 13494/2200 means a ljungstrom air preheater with rotor diameter of 13494 mm，The height of heating elements of 4 sections are respectively 300 mm ，800 mm,800 mm and 300 mm from top to bottom of the rotor. The cold end heating elements of 300 mm height are made of Corten plate, while the hot end heating elements are made of common carbon steel，The metal weight of one air preheater is approximately 620 ton, including 465 ton for the rotor assembly (about 75 percent of the total weight). The air preheater is tri-sector type.

5.1 Principle

The type of LAP 13494/2200 tri-sector rotary air preheater is a counterflow regenerative heat exchanger. Specially corrugated heating elements are tightly placed in the sectorial compartment of the rotor. The rotor turns at a speed of 0.99 rpm and is divided into a gas channels and an air channels. The air side is made of first air channels and second air channels，When gas flows through the rotor, it releases heat and delivers it to the heating elements and then the gas temperature drops; when the heated elements turns to the air side, the air passing through them is heated and its temperature is increased. By continuing maintaining such a circulation the heat exchange is achieved between gas and air. It is not only an important component for utility boilers but also an ideal heat exchanger widely used in various industries of today's world to save energy and increase efficiency.

Enclosed by an enneahedral housing assembly, the rotor is supported by a thrust bearing mounted on the center of the lower center section and guide bearing mounted on the center of the upper center section. Both sections are connected to the rotor housing assemblies，which are supported by structure steel. The rotor drive unit provides a speed of 0.99 rpm for the rotor. In order to prevent leakage of air into gas side, radial, axial and bypass seal devices are arranged respectively along radial direction at both ends, axial direction and circumferential direction of the rotor. Double radial and axial seals reduce

the direct leakage of air preheater. In addition, the air preheater is also equipped with sootblower, water washing, lubricating oil system, infrared fire alarming, and sealing control system (see FIG. 1 and FIG. 2).

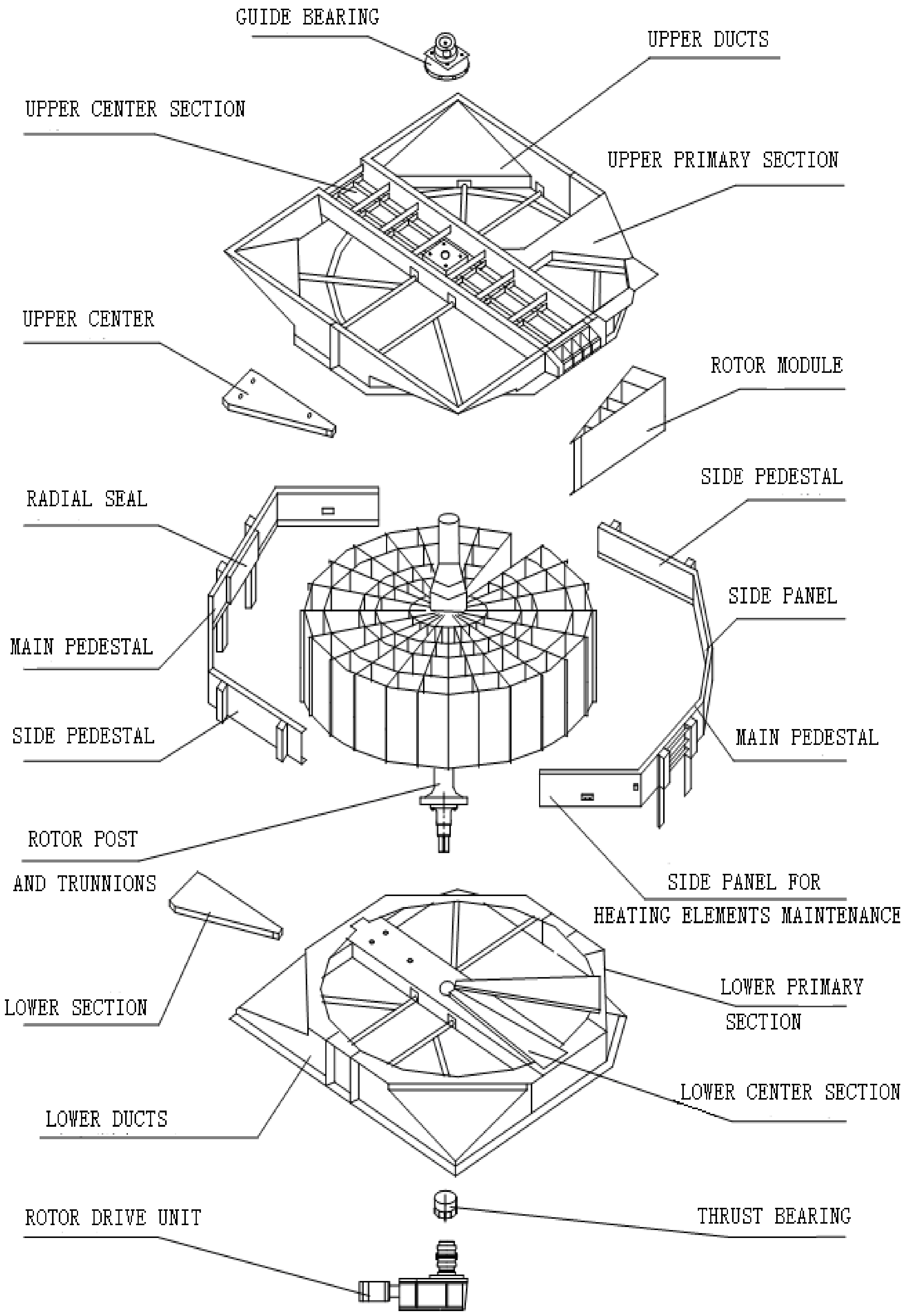

GUIDE BEARING
UPPER DUCTS
UPPER CENTER SECTION
UPPER PRIMARY SECTION
UPPER CENTER
ROTOR MODULE
RADIAL SEAL
SIDE PEDESTAL
SIDE PANEL
MAIN PEDESTAL
MAIN PEDESTAL
SIDE PEDESTAL
ROTOR POST
AND TRUNNIONS
SIDE PANEL FOR
HEATING ELEMENTS MAINTENANCE
LOWER SECTION
LOWER PRIMARY
SECTION
LOWER CENTER SECTION
LOWER DUCTS
ROTOR DRIVE UNIT
THRUST BEARING

Figure 1

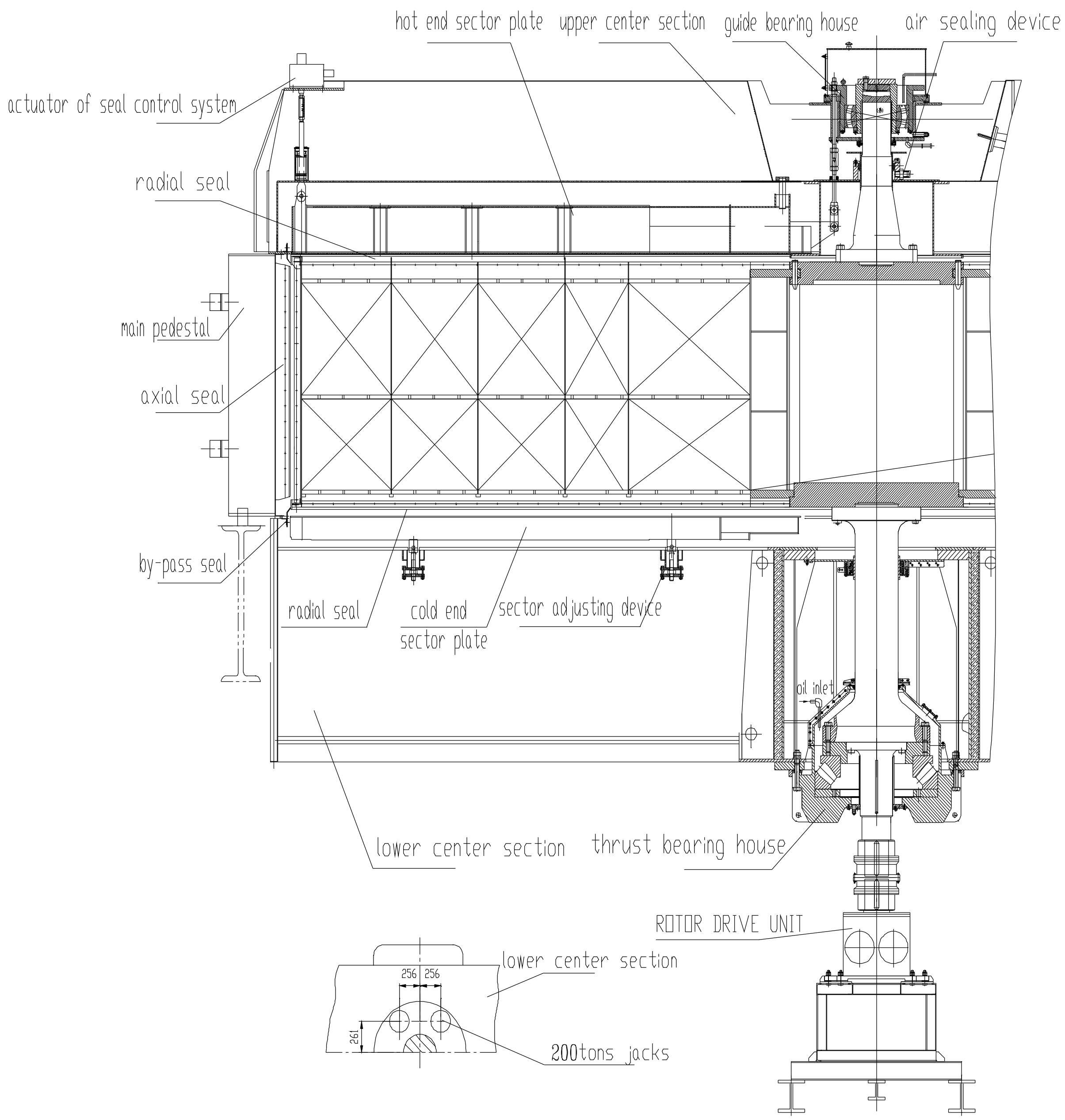


Figure 2

5.2 .Main components and their functions

5.2.1 Rotor

The modular compartment structure is adopted for the air preheater rotor. All the heating elements are respectively arranged in 24 sectorial modules (15°angle for each module, further more, one module is separated into two parts with partition plate for the reason of double radial and axial sealing) （See the FIG.4）. Each rotor modules are

connected to the rotor post in the form of pin connection to facilitate installation. The forged upper and lower trunnions are respectively connected to the upper and lower ends of the rotor post by M52 AND M42 bolts made of alloy steel (lower trunnion and extending trunnion is connected with M42 alloy steel bolts) to form an integral rotor shaft of the air preheater. Two adjacent rotor modules are connected by bolts. Hot end heating elements are placed into modules from rotor top, while cold end heating elements from manholes arranged on rotor periphery. Our company supplies the hook plate for the maintenance of cold end heating elements. L-shaped arc bars and are T-shaped arc bars arranged in areas with maximum diameter at upper and lower ends of the rotor to serve as bypass seal elements. The L-shaped arc bars are served as datum surface to measure rotor deformation. The L-shaped arc bars' upper surface, the L-shaped arc bars and T-shaped arc bars' side surface situated in the area with maximum diameter will be machined in site by turning the rotor itself and with the cutter holder supplied by our company.

5.2.2 Heating elements

Made of carbon steel sheets with special corrugations formed by pressing, the hot end heating assemblies are profiled in accordance with shapes and sizes of individual sub-modules. Each assembly is formed by alternately piling up notched undulation sheets with vertical undulations and inclined turbulent corrugations and sheets only with the same inclined corrugations one by one.

The cold end heating elements are made of Corten plate. The assemblies of cold end heating elements are alike profiled in accordance with shapes and sizes of individual sub-modules but each assembly is built up alternately by position sheets with vertical undulations only and flat sheets. （See the FIG.3）

All the assemblies of both hot and cold end heating elements are soundly fastened by means of flat bars, angle steels welded together. In case lower cold end heating elements are subject to corrosion, they can be readily reversed during repair and maintenance for extended life by simply lifting, cleaning and turning over in the rotor to continue their serve time until they are corroded again. If heating element corrosion is so serious that corroded

chips drop from time to time and the exhausted gas temperature or safe operation are badly influenced, the cold end heating elements shall be replaced.

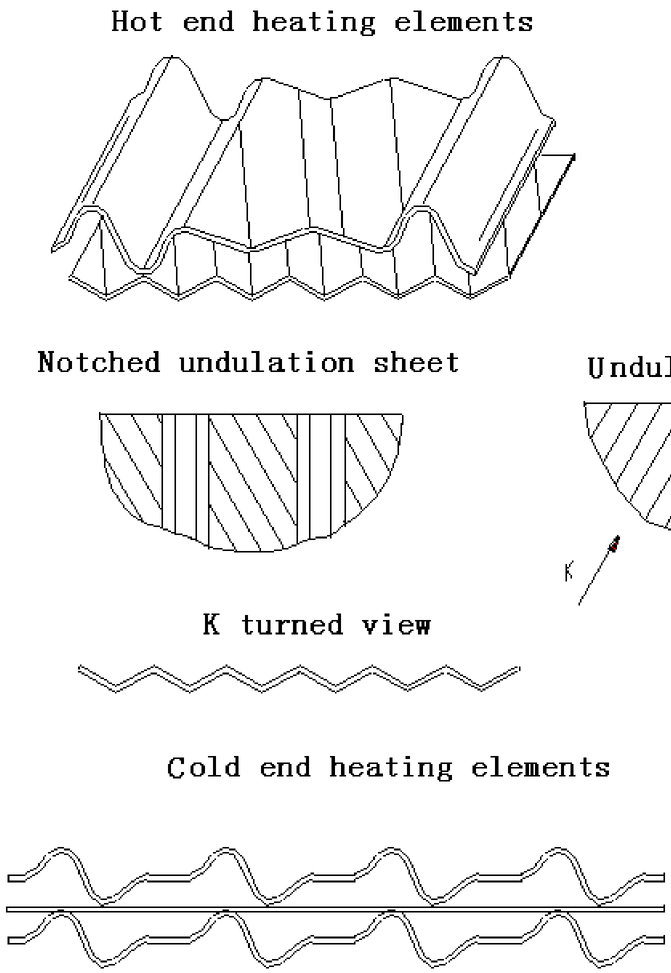


Figure 3

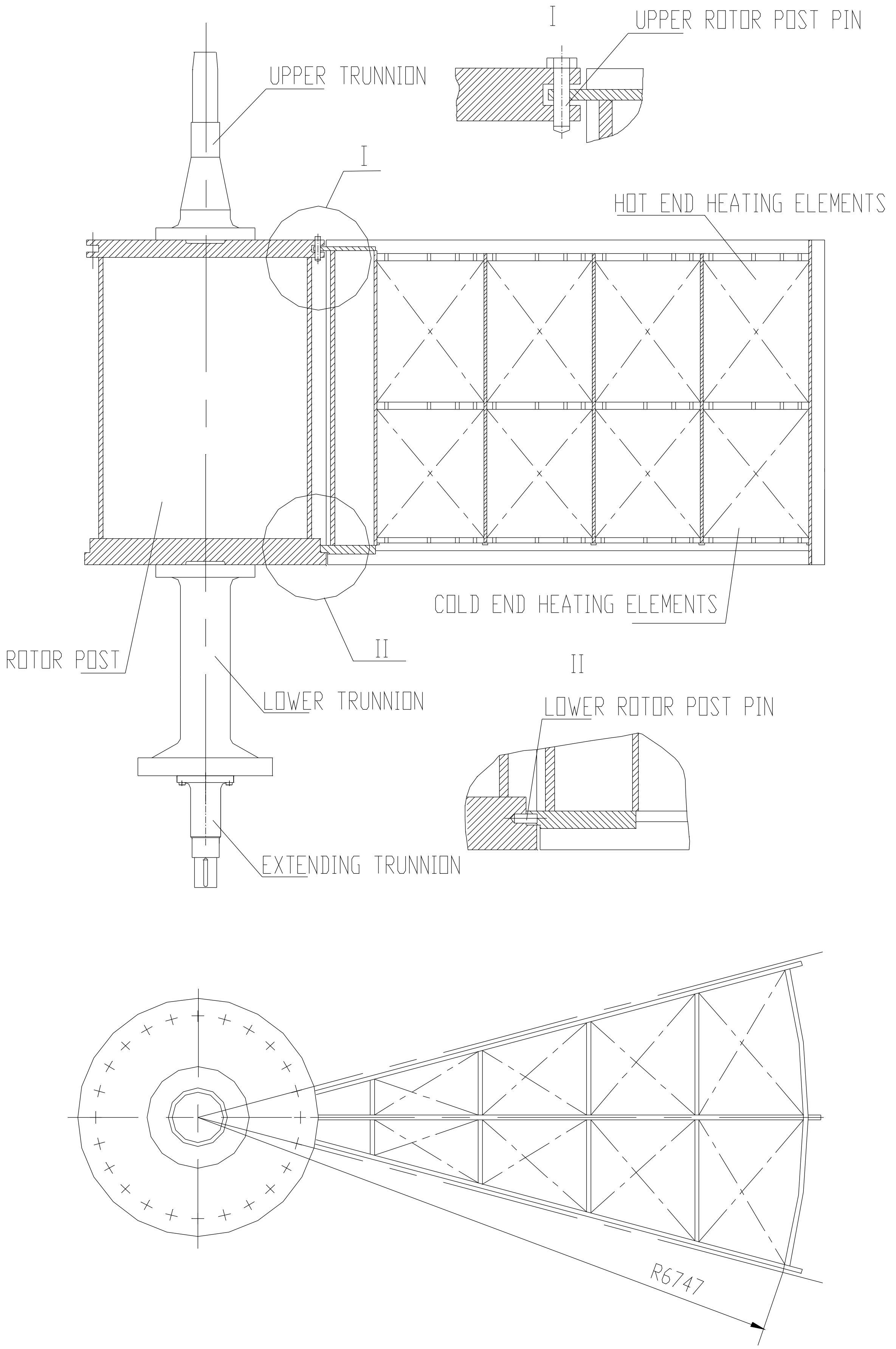

I
UPPER ROTOR POST PIN
UPPER TRUNNION
I
HOT END HEATING ELEMENTS
COLD END HEATING ELEMENTS
II
ROTOR POST
LOWER TRUNNION
II
LOWER ROTOR POST PIN
EXTENDING TRUNNION
R6747

FIG. 4

5.2.3 Rotor housing（129YR2-0）

The enneahedral housing consists of 3 main pedestals, 2 side pedestals and 4 side panels (see Fig.5).

Connected with both lower and upper center sections, the main pedestal Ⅰ and main pedestal Ⅱ will deliver most of loads of the air preheater to boiler structure steel via their 4 columns. Tile-shaped axial seal devices are arranged on inward sides of the main pedestals and several adjusting points on outward sides to adjust the seal device positions.

Side pedestal are divided into three parts along the width direction. The middle part of the Side pedestal can be moved aside for the entrance of installing heating element baskets. Our company supply the "Side pedestal installation" in order to make sure side pedestals' stability when fixed. Side pedestals also have 4 columns via which a small portion of loads of the air preheater is delivered to boiler structure steel.

Arranged along 45°and 25°direction there are 4 side panels for the air preheater. Side panels are equipped with 508×508 manholes so as to make it accessible to adjust and repair the axial seal and axial seal device inside the air preheater.

In order to cater for radial expansion of the housing, expansion supports are arranged under columns of the main pedestal Ⅰ and Ⅱ and the side pedestals. Plane friction couples are adopted as expansion slide surfaces, which are made up of 3 layers combination self-lubricating material. Moreover, stoppers are fixed on the inside of each pair of expansion supports to prevent the air preheater from horizontal displacement and to serve as guide blocks of radial expansion for the housing. Both main and side pedestals are provided with brackets fixed on the lower parts of their columns to hold jacks for adjusting shims of the expansion supports.

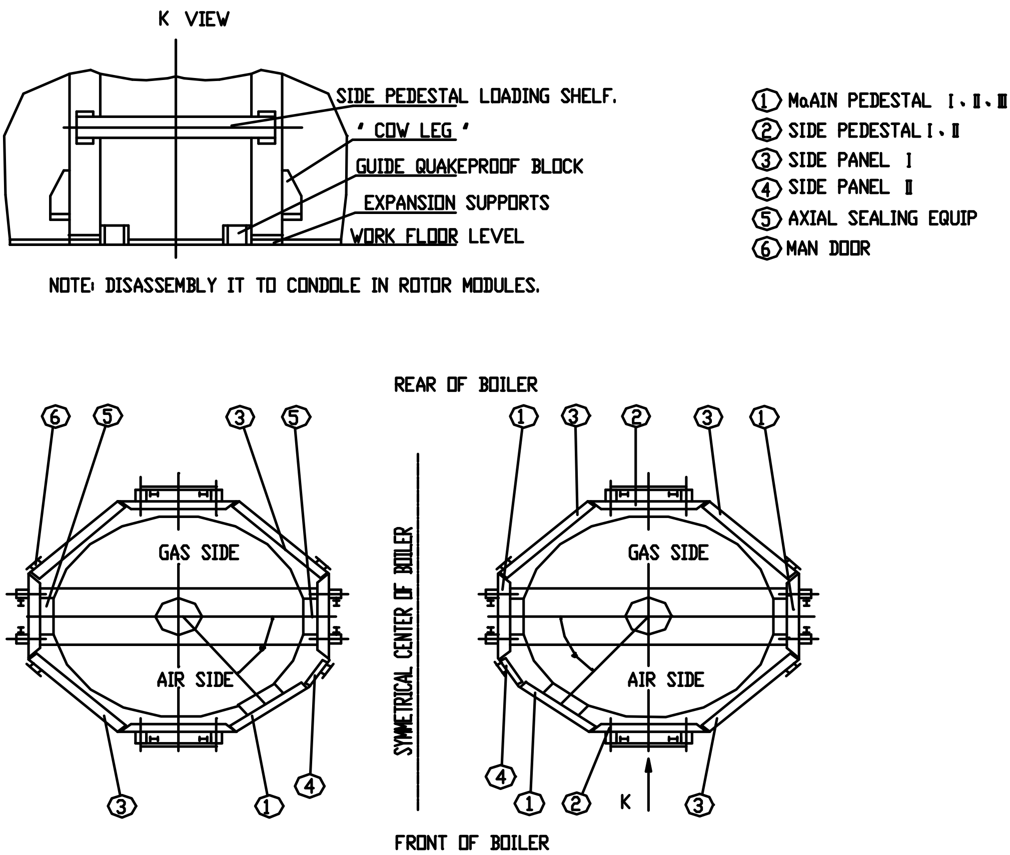


FIG. 5

5.2.4 Center sections, sector plate and gas/air ducts

Center sections, sector plates and gas/air ducts By connecting both upper and lower center sections to main pedestal Ⅰ and Ⅱ a closed framework is formed which is the main structure to support rotary part of the air preheater. The upper and lower center sections are also designed to divide the air and gas flows, while the upper and lower primary center sections to divide primary air and secondary air, forming gas, primary and secondary passes. Sector plates are fitted on both the upper and lower center section and the upper

and lower primary center sections to form a main sealing surface, the radial seal between sector plates and seal leaves. Static seal device are fitted between sector plates and the center sections, primary center sections at gas side and secondary air side.

A thrust bearing which withstands the whole load of rotary part of the air preheater is mounted on the center of the lower center section, which looks like a double-wed hollow beam. Both ends of the center section are connected by welding to heavy thick plates which are extended from columns of the main pedestal Ⅰ and Ⅱ. A reinforced plane is provided in the center area of the lower center section for holding jacks so that it is available to lift the rotor for the repair and maintenance of the thrust bearing (see Fig. 2). 3 abutments are provided for each cold end sector plate and are mounted on the center section. With different building-up of shim thickness for each abutment, slight position adjustment is available for sector plates so as to satisfy seal requirements. In order to prevent sector plates from horizontal movement as a result of pressure differential between gas side and air side, 2 guide levers for each sector plate are arranged on the lower center section. The packing is loaded around with the axis to form the sealing, and the particular description can see the drawing129YR62-0(thrust bearing)

The cross section of the upper center section appears in a concave rectangle. both ends of it seat on the top ends of the main pedestal Ⅰ and Ⅱ. 3 fulcra are provided for each hot end sector plate, one at inner of the sector plate, two at outer. The inner fulcrum is suspended by the bushing of the guide bearing and can move up and down with the air preheater shaft thermal expansion, so as to ensure that the inner part of the hot end sector plate follows rotor thermal deformation and to avoid excessive wear abrasion of inner part of the radial seal leaves. The 2 outer fulcra are connected via sling bars with the actuator of the seal control system (129YR33-0), which programs the hot end sector plate to automatically cater for rotor mushroom shaped deformation during operation. 2 guide levers for each sector plate are also arranged on the upper center section to prevent horizontal movement of the plate.

Upper axis sealing systems are made up of center sealing sleeve and air sealing

device. The sealing air of air sealing device is derived from the outlet of the primary air fan to obtain a higher pressure than outlet air pressure of air preheater. There are manholes (600×700 or 508×508) in the upper and lower gas/air ducts. Adjusting floor (129YR93-0) is installed in the lower gas/air ducts for ambulate when maintenance.

5.2.5 Sealing system

Advanced radial-axial and radial-bypass double sealing systems are adopted for the air preheater. Radial and axial sealing effectiveness is further enhanced by a double sealing system that creates a moving plenum across the sealing surface. The formation of this intermediate-pressure plenum between the air and air flows serves to reduce the air-to-gas pressure differential by a factor of nearly two. This decrease in pressure differential can reduce direct leakage by as much as 30 percent. The double sealing systems have a short periphery of seals and therefore work well (see Fig.6).

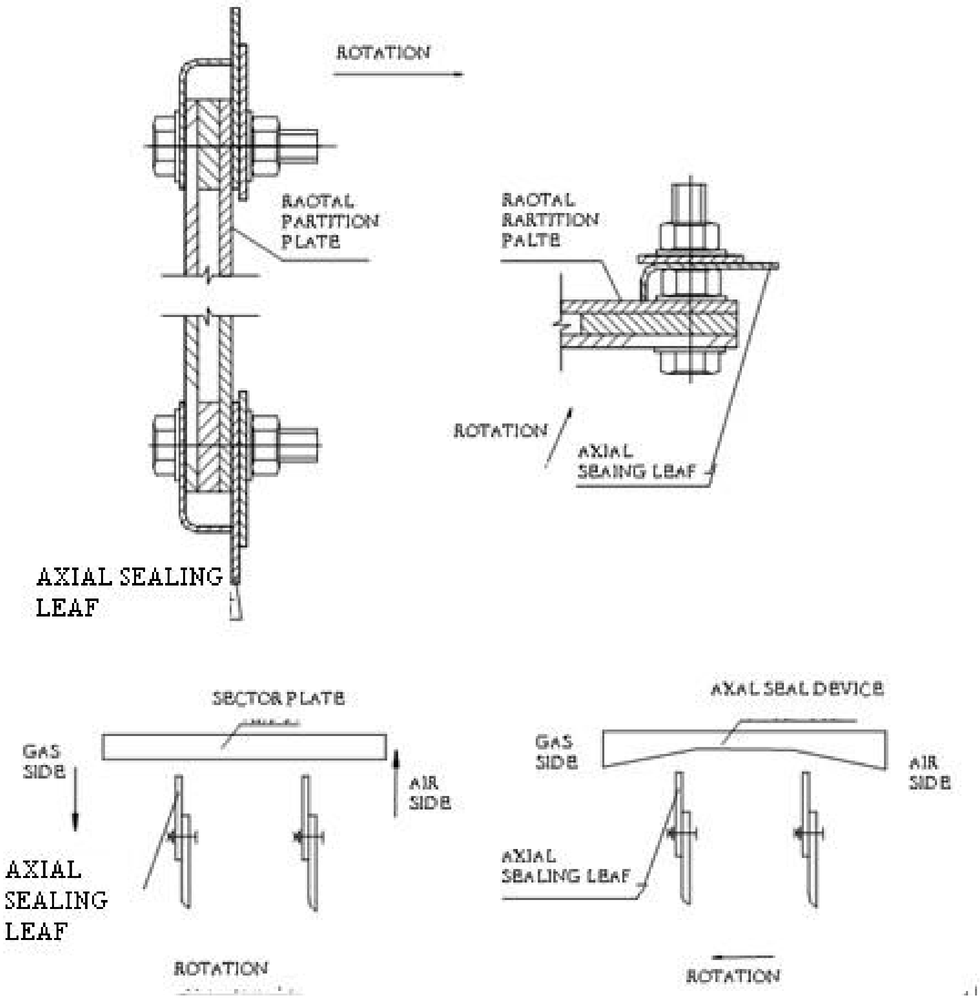
Radial seal leaves are made of 1.5 mm thick corrosion- resistant low alloy steel plates and are divided into 4 sections along their entire length and bolted on radial partition plate of rotor modular compartment. Radial seal leaves are appropriately adjustable in height due to the slot holes machined on them.

Axial seal leaves are alike made of 1.5 mm thick corrosion-resistant low alley steel plates. The leaves are also bolted on radial partition plate of the rotor modular compartment and are adjustable along radial direction of the rotor (see Fig.7).

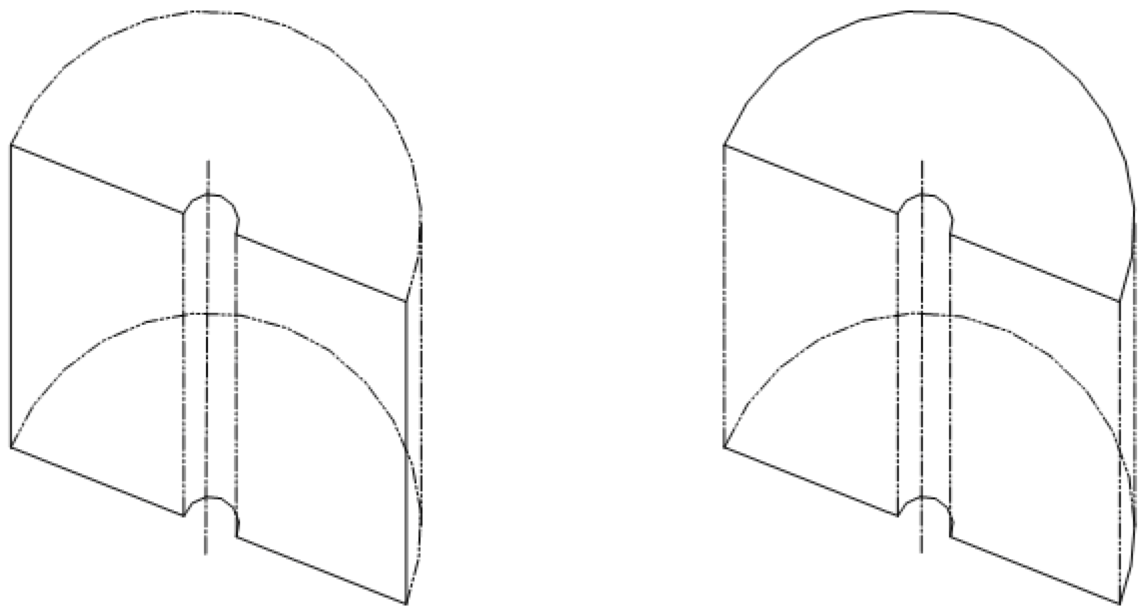
The radial seal system is made up of radial seal leaves and sector plates, while axial seal system by axial seal leaves and axial seal devices. Aluminium ring and padding seals are adopted for the upper and lower trunnions. All the above forms a continuously closed seal system.

In addition, a circumferential bypass seal system is provided at both ends of the rotor to prevent gas or air from entering space between rotor and the housing. It plays a certain role in sealing as the first axial seal defense line. Made of 1.2 mm thick corrosion-resistant low alley steel plates, the bypass seal leaves form a bypass seal with the T-shaped rings

(L-shaped rings) on rotor periphery, but it stops at sector plate area where another sealing parts are arranged to connect with the aforesaid seal and form an entire circle of bypass seal.



(FIGURE 6)



RADIAL AND AXIAL SEAL SYSTEM

AXIAL AND BYPASS SEAL SYSTEM

（FIGURE 7）

5.2.6 Rotor drive unit（129YR52）

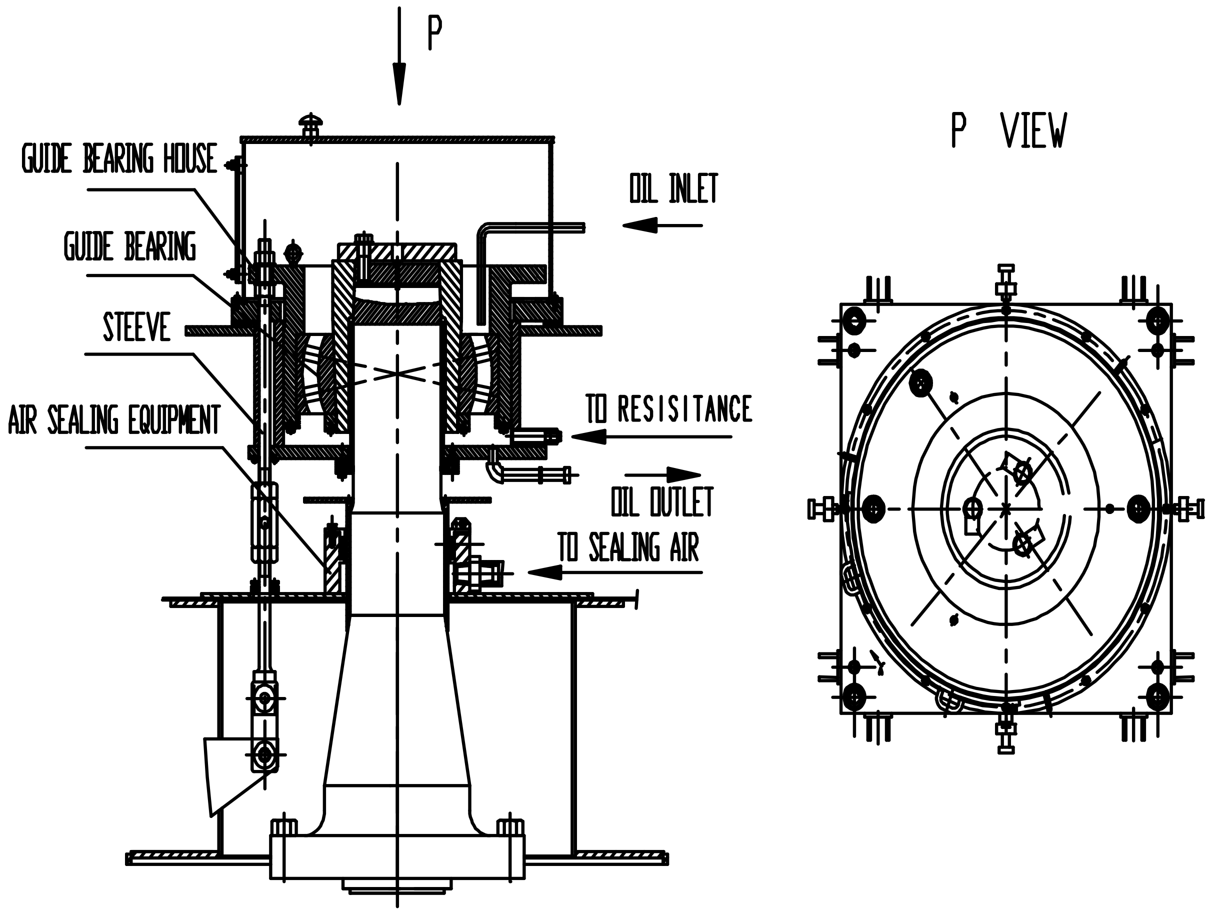
Rotor drive unit is located under the thrust bearing. The rotor drive unit of consists of one reducer and one main electric motor. Use the transducer to start the reducer and main electric motor，and there is a device to control the transducer. For detail see "Specification for rotor drive device" and “Specification for operating the rotor air preheater’s electric control box”

5.2.7 Guide and thrust bearings

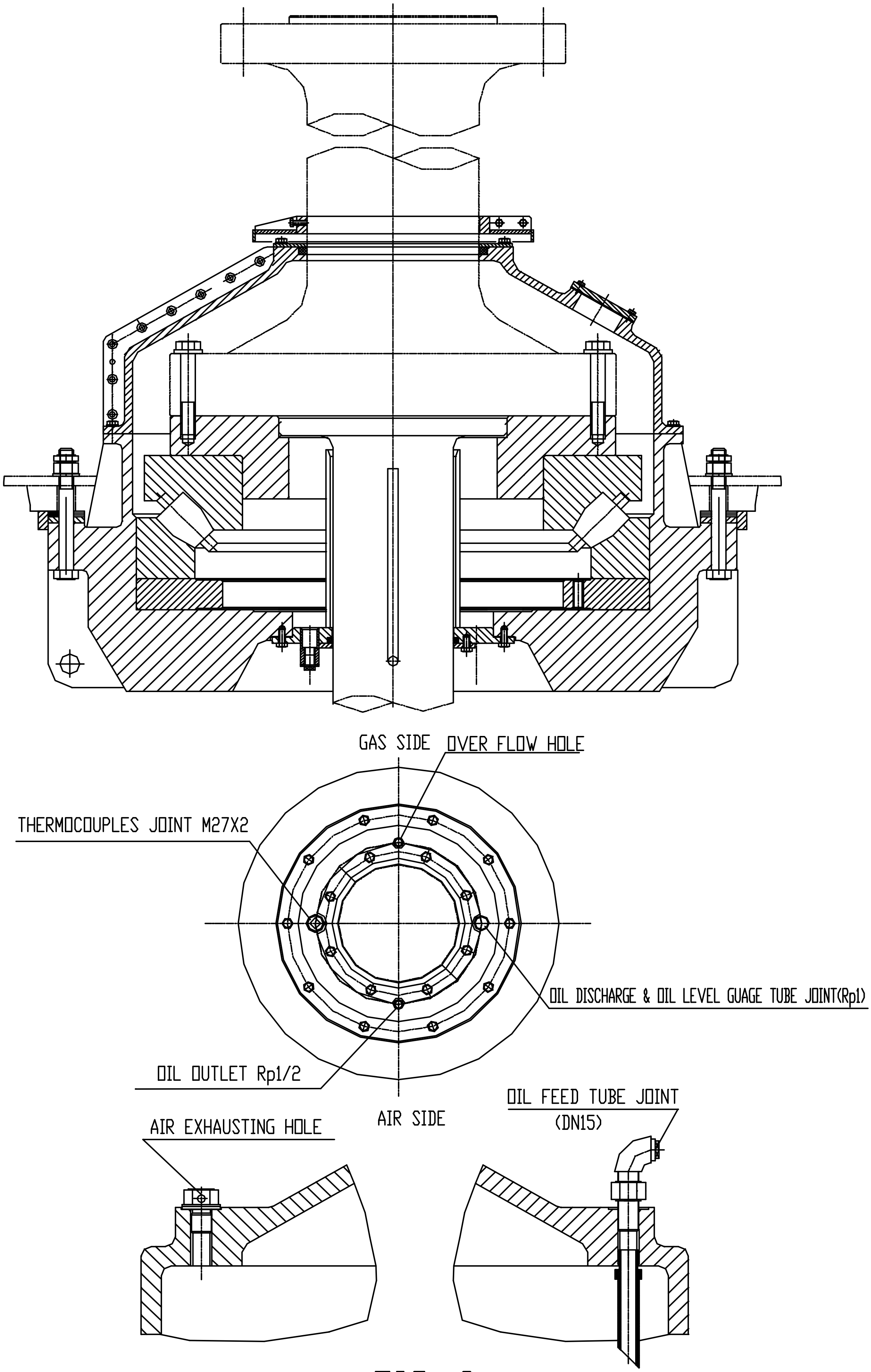
The guide bearing is a double-row radial roller bearing with its inner ring fixed on the upper trunnion bushing and its outer ring on the guide bearing bushing (129YR61-16). The guide bearing bushing can axially move, with thermal expansion of the air preheater shaft in its housing which is installed at the center of the upper center section. Air sealing device is adopted for the sealing and cooling of guide bearing. Guide bearing shell is installed in the middle of the upper center section, and the bearing is lubricated by oil bath and oil circulation with the industrial gear oil 150# and 30 liter in capacity. The guide bearing bushing is connected via 3 sling bars with the hot end sector plate so that the plate can follow thermal expansion of the rotor shaft. The guide bearing assembly is

equipped with ports for oil suction and oil feed, an oil discharge tube joint an oil flow meter and a flanged tube joint for installing thermocouples. (See the FIG.8)。

The thrust bearing is a radial thrust roller bearing DG-AH-750 with its inner ring fixed to the lower trunnion via a coaxial retaining plate and its outer ring rested on the thrust bearing housing which is fixed securely on the bottom surface of the lower center section via 36 alloy steel bolts of M48×390. The thrust bearing is lubricated by oil bath and oil circulation with industrial gear oil 150# and 500 liter in capacity. The thrust bearing housing is also equipped with miscellaneous items similar to what the guide bearing assembly is with mentioned above for the same purpose (see Fig.9).



（FIGURE 8）



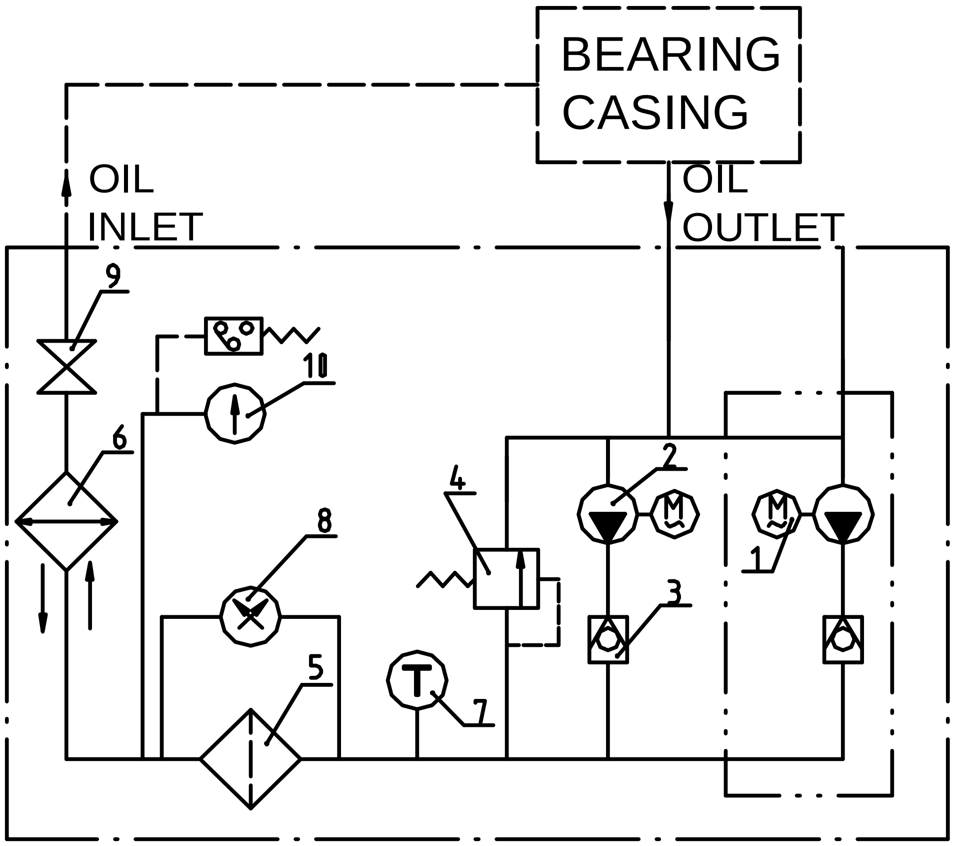
GAS SIDE
OVER FLOW HOLE
THERMOCOUPLES JOINT M27X2
OIL DISCHARGE & OIL LEVEL GUAGE TUBE JOINT(Rp1)
OIL OUTLET Rp1/2
AIR SIDE
OIL FEED TUBE JOINT
(DN15)
AIR EXHAUSTING HOLE

FIG. 9

5.2.8 Guide and thrust bearing lubricating oil system（129YR71.129YR72）

The DGXYZ- 26 and DGXYZ- 26D thin oil stations are adopted respectively for the guide bearing and the thrust bearing. (See Fig.10). The guide bearing thin oil station is directly located on the air preheater platform close to the upper center section. In order to make sure the safety of working, the guide bearing thin oil station is loaded two pumps that one foe operating and one for standby. The oil entering and outing pipes serves as the oil suction pipe for the guide bearing. The thrust bearing thin oil station is located on the maintenance platform, and connected with the thrust bearing using pipes.

A double oil pump construction thin oil station is adopted for the guide bearing and a single pump construction thin oil station for the thrust bearing. The 2 units are similar in construction and each consists of 3Gr30×4 type 3-screw pump device (motor model Y90L-4, 1.5KW, n=1410rpm, pump oil flow 1.2m3/h, system maximum working pressure 0.6MPa), screen filters, tubular oil cooler, oil temperature indicators, pressure gages, pipelines, valves and oil flow watching meters etc (see Fig.10 and "DGXYZ thin oil station operation specification") . Ordinary industrial water is served as cooling water with working pressure P=0.2~0.3MPa. Normal situation consume 70Kg/min, the max consume 100Kg/min. The oil pump is controlled by the control panel, starting at 55℃, stopping at 45℃ and alarming at 70℃.



NOTE: 1.WIPE OFF DOUBLE DASHDOTTED IS SIGLE PUMP;
2.OUT SIGLE DASHDOTTED'S BROKEN LINE IS COMPOUNDED AIR BY PREHEATER PRODUCER.

5	DOUBLE SLEEVE WEB OIL FILTER	SPL25C (1202[illegible])	10	ELETRIC-CONTACT PRESSURE METER	XY-150 (0~1MPa)
4	SAFETY VALVE	AQF-25	9	GLOBE VALVE	G1"
3	NON-RETURN VALVE	DXF-25	8	DOUBLE INDEX PRESSURE METER	YZS-102
2	3-SCREW BUMP	3GR25X4-0.8/1.0	7	DOUBLE STEEL THERMOMETER	WSS-411 (0~100℃)
1	MOTOR	0.75kw, 1410rpm	6	PIPE COOLER	GLC1-1.0
No.	NAME	TYPE	No.	NAME	TYPE

（FIGURE 10）

5.2.9 Fire alarming, fire fighting and water washing device（129YR82）

A cleaning pipe with diameter 159×12 is arranged for either of hot end and cold end of the air preheater at the gas side starting area according to rotation direction of the rotor to facilitate washing water discharging form ash hopper at gas side. On the cleaning pipe, nozzles with different diameters are fitted to obtain a uniform distribution of washing water for heating surface inside the rotor to achieve a good washing result. 0.59 MPa normal

temperature industrial water is used as the washing medium and 60℃-70℃ warm water may be also used. The capacity is 4600 kg/min for each cleaning pipe. These cleaning pipes can also be used for fire fighting and should be connected flexibly during installation is site.

The infrared fire alarming system is installed in the cold air side of air preheater. The detector is horizontal moved back and forth for detecting the fire in the air preheater.

5.2.10 Sootblowing device (129YR81)

One back and forth sootblowers with steam as working medium is arranged at gas side under the cold end heating elements for one air preheater.

A motorized chain drive device makes it available for the blower to move from side to side during steam purging. Parameters concerned are given below:

Motor (model AO2-6324-B5 5F): 0.18 KW, 1370 rpm

Stroke: 1168mm

Steam pressure: 1.5 MPa

Steam temperature: 350 ℃

Steam consumption: 2×100 kg/min.

Move speed of nozzles: 1.44m/min

Total operating time: 40 minutes/once

The sootblower has 4 Φ16 nozzles, and the per blow process can use 2×4000kg steam.

The blower operation procedure can be controlled by process or single working of the blower shall be subject to specification given by the blower maker. And the blower operation process is included in the sootblower of boiler operation system.

5.3 Indicating instruments, operation and control system

Instruments for operation and control listed below shall be provided to ensure safety

and economic operation.

№	Indication	Operation and Control	Remark
1	Flue gas inlet and outlet temperature		
2	Air inlet and outlet temperature		
3	Gas inlet and outlet Pressure		
4	Air inlet and outlet pressure		
5	Oxygen content at gas inlet and outlet		
6	Main electric motor	Auto/manual	interlock
7	standby electric motor	Auto/manual	
8	*Guide bearing oil pump red and green lamps	Auto/manual	The oil pump is started at 55℃, stopped at 45℃ and alarm given at 70℃
9	*Guide bearing oil temp indicating and overtemperature alarming control	Auto/manual	
10	*Thrust bearing oil pump red and green lamps	Auto/manual	The oil pump is started at 55℃, stopped at 45℃ and alarm given at 70℃
11	*Thrust bearing oil temp indicating and overtemperature alarming control	Auto/manual	
12	Rotor stoppage alarming		Ring plus light letter lamp
13	Trouble alarming for seal control system		

14	Trouble alarming for infrared fire alarming system		

5.4 Starting up and trial operation

5.4.1 Starting up

The following items shall be performed and ensured before initial and consequent starting up.

1) Make sure that there are no people, tools and foreign substances inside the air preheater.

2) Close tightly all manholes, inspection doors after checking up of specified personnel.

3) Turn the preheater with the hand wheel. If nothing abnormal occurs, then start up the air preheater by the standby electric motor for several turns at low speed.

4) Check up whether the guide bearing oil level situates within the normal range, oil temperature is lower than 55℃ and cooling water circulation of various self-lubricating systems is normal. If the oil temperature exceeds 55℃, start up the oil pump by manual mode to reduce it down to the specified value and then look for the reason.

5) Check up the reducing gear oil level to see whether it situates within the normal range.

6) Make sure the radial and axial seals are soundly adjusted for both the hot and cold ends and so for the hot end radial seal auto-control system (it should be in upper limit position), including sensors and actuators.

7) The sootblower, cleaning pipes should be in the state ready for use.

8) All indicating instrumentations, control and power circuits are in normal working state.

5.4.2 Trial operation

A 4-hour trial operation should be performed at cold condition for the air preheater after finishing its erection and such a cold operation for 2-4 hours should be performed

after each overhaul of it.

In addition to the preparation work given in 4.1 before trial operation the rotor turning direction should be checked by starting the drive motor instantaneously to guarantee it turns in the same direction as specified by drawings.

Items for "Patrol inspection of normal operation" (Section 5) should also be inspected, necessarily recorded item by item during trial operation. In case of any abnormal, the trial operation should be stopped. After removal of defects renew the trial operation.

5.5 Patrol inspection during normal operation

During normal operation of the air preheater the operation personnel should carefully observe those indicating instruments mentioned in section 3 since any abnormal display of them is a signal of maloperation of the preheater. If the flue gas and air pressure differentials between inlet and outlet of the preheater keep a sustained increase and they can not be restored although intensified steam purging is taken, it means the heating elements have been seriously contaminated and choked and the preheater needs washing with water in the next boiler outage. If the hot air and the exhausted flue gas temperatures go up suddenly and are 50℃ higher than the normal, there will be the likelihood that the preheater is fired (the "secondary combustion"). In this case, operation personnel must take emergency measures.

During boiler normal operation the temperatures and pressures of gas and air inlets should conform to design requirements and following data are for reference in operation detection of the air preheater:

Guide bearing oil temperature: < 55 ℃

Thrust bearing oil temperature: < 55 ℃

Seal clearance indicating value of hot end sector plates: 0.

The following items should be inspected by operation personnel in their routine patrol inspection of normal operation of the air preheater:

1) Check the air preheater to see if any abnormal noises exist.

2) Reducing gear oil level of the motorized drive device should be normal an the oil temperature and the fluctuation temperature shall not exceed 60℃, when the main electric motor is in service, no turns should occur for the standby electric motor. There are no abnormal vibrations, oil and gas leaks.

3) Oil levels of the guide and thrust bearings should be normal and no oil leaks occur for the bearings and the cooling water of oil coolers flows smoothly with outgoing water temperatures below 30℃.

4) Observe oil temperature indications of guide and thrust bearings at local panels, which should be lower than 55℃, and the seal clearance indications of hot end sector plates.

5.6 Outage

5.6.1 Hot retention stoppage of boiler

Usually the gas dampers are closed to minimize boiler heat loss after the boiler is shut down by cutting off fuel, stopping forced and draft fans for a short period of stoppage in hot retention condition.

Operation personnel must operate according to the following procedures to avoid the secondary combustion of the air preheater as a result of the heat accumulation inside it in this case:

1) Before the stoppage of boiler, the preheater shall be steam purged.

2) Keep the heater turning.

3) Carefully monitor temperature indications of gas inlet and air outlet. This is because their temperatures will keep a sustained increase tendency with hot air flow going up in case of occurring of the secondary combustion inside the air preheater.

4) Manholes should be kept in closed condition to avoid unnecessary air entering into the preheater.

5.6.2 Normal shut down of boiler

If the boiler is intended to keep a long period of shut down in cold state following operations shall be performed in sequence:

1) Before boiler shut down the preheater shall be steam purged once and steam purged once more after the boiler is unloaded down to 60% MCR.

2) Keep the preheater turning until gas temperature at inlet of the preheater decreased to 150℃ after boiler burners are withdrawn.

3) Keep lubricating oil and cooling water systems in service until oil temperatures of the guide and thrust bearings are below 45 ℃ after the preheater stoppage.

4) The gas and air temperatures at outlets should be monitored when the forced fan is still in operation; the inlet gas temperature and the outlet air temperature should be monitored after the fan is shut down because there is a likelihood of the secondary combustion inside the preheater.

5) The water washing of the air preheater shall not be performed unless the inlet gas temperature of the heater is decreased down to 200℃ after the boiler shut down. After washing, the heating elements of the preheater may be dried by the bioler residual heat.

5.7 Sootblowing

Purging the air preheater with steam is imperative to ensure it operates safely and economically. The purging cycle will depend on the degrees of fouls of heating elements. In the primitive operation period of the preheater, it can be purged once every 24 hours and this cycle can be increased or decreased in accordance with actual operation practice after continuous operation of the air preheater.

The following measures are recommended when fuel changes significantly and when in starting up, shutting down or operation at 50% MCR of the boiler:

1) Time for oil firing should be as short as possible.

2) Steam purging should be once every 4-8 hours.

3) Improve the inlet air temperature to keep the average temperature of air preheater cold end higher than the dew point temperature, by means of air steam heater or hot air re-circulation.

Tightly close the valves in the steam pipes to avoid the fouling caused by steam leakage.

5.8 Cleaning

If, as mentioned above, contaminators (fouls) on the heating surface of the air preheater can not be removed even by intensive steam purging and the gas and air flow, resistances are 70-100 mmH2O higher than the normal, the air preheater needs washing after normal shut-down of the boiler.

5.8.1 Cleaning methods

1) Shut down the boiler and start up the standby motor to keep the air preheater turning at low speed. Situate hot end sector plates at the emergency lifting (upper limit) positions.

2) Washing should be performed after the gas inlet temperature decreases to 200℃ and dampers at gas inlet and air outlet should be closed.

3) Evacuate collected ashes from hoppers located under the air preheater and open water discharge doors.

4) 60-70℃, 0.59MPa washing water is preferred and normal temperature water may also be used for washing. The upper and lower washing pipes with a flow of 4600kg/min each, arranged for the air preheater should be put into service simultaneously.

5) If contaminators (fouls) on the heating surface appear in hard lumps, interrupting water supply for half an hour is suggested here to make the lumps become soft.

6) If the contaminator (fouls) appears in acidity add NaOH chemical into the washing water to obtain a good result of cleaning.

7) A better cleaning result can be achieved by water washing plus steam purging if

purging steam is available during the cleaning an in this case, steam below 250℃ is allowed.

8) After the cleaning, the heating surface shall be fully dried. As a rule drying by the boiler residual heat should keep for at least 4-6 hours by opening the gas flow dampers.

9) Valves on cleaning pipes shall be tightly closed.

10) The discharged water should be disposed to avoid environment pollution.

5.8.2 Acceptable criterion for cleaning

It's acceptable for the cleaning when there are few ash particles and a value of PH6-8 in the discharged water. Depending upon contamination (fouls) and choking conditions of the heating surface, time to be lasted and water to be consumed are not predicted for the cleaning but as a rule it will consume 1-1.5 tons of washing water to reduce every 1mmH2O of flow resistance.

5.9 Trouble shooting

5.9.1 Current rise-up of electric motor

In normal operation, the current of the main drive motor is stabilized at a value of 5.8.3A with a fluctuation not larger than ±1.5 A.

If a large fluctuation of current suddenly occurs, accompanied by clash noises, with a frequency of once in every about 30 seconds, it will be likely that some foreign matters drop on the rotor surface or some parts/elements of the rotor are projected over the surface so that strong frictions take place between them and sector plates.

In this case, the first thing to be done is to lift the hot end sector plates up to "emergency lifting positions". If the maximum current doesn't exceed the rated and the fluctuation to a certain decree is alleviated, the air preheater may maintain its operation or shut down the boiler by gradually unloading it to zero. Keep the air preheater turning until the gas inlet temperature drops to 200℃. If the current exceeds the rated and has no tendency of reduction, boiler emergency shutdown shall be performed and try to maintain the air preheater running until the said gas temperature drops to 200℃.

If the current fluctuation emerges with a frequency of once in less than 1 seconds, it is likely that the cold or hot end sector plates or the axial seal devices are not properly adjusted, which frequently takes plate in initial operation after erection or overhaul. In this case, it is necessary to try to find out which sector plate or axial seal device is too small in clearance pre-adjusted so as to readjust it after boiler shut down. For hot end sector plates, removal of the fluctuation can be achieved by changing their clearance-presetting values or by lifting them in manual mode.

Serious erosions will occur for seal leaves and sector plates if the air preheater is kept continuously operating in the condition that the current fluctuation is large, although the peak current is below the rated.

The current increase of the drive motor can also be a prelude that the guide or thrust bearing has damaged but in this case, rising of bearing oil temperature, sinking of the rotor and increasing friction between radial seal leaves and cold end sector plates are frequently accompanied. In case of damage of bearings, boiler emergency shutdown shall be performed and the air preheater shall be kept turning until the aforesaid gas temperature drops to 200℃.

5.9.2 Sudden stop of air preheater

In case of a sudden stop of the air preheater during operation the seal control system will give alarming within 25 seconds, and lift hot end sector plates to the "emergency lifting positions".

If in this case the current of the drive motor remain normal, it means the electric motor remain working and the trouble comes from the reducing gear itself.

If the current goes up to the maximum value and even is tripped, it means the rotor is stacked with foreign matters or the guide, thrust bearing damaged.

The sudden stoppage of the air preheater will create troubles for its restart and even cause significant damages for bearings and the preheater proper for it remains in gas and air streams which will result in odd deformation of it. In this regard, one thing very

important is to restore turning of the air preheater as soon as possible in case of such a sudden stoppage. Try to restart up the air preheater 1 to 3 times by means of the main or standby electric motor if the rotor can be turned over 1 turn by manpower such as by using the hand wheel or open the man holes which are on the side panel and basket removal door panel then using the haulm to turn the air preheater. Naturally, if the sudden stoppage is caused by the interrupt of main power supply, the thing merely to do is starting up the standby electric motor (spare power supply) to restore the operation. However, in taking measures to restore normal operation of the air preheater it's very important to find out what the troubles result from and remove defects as soon as possible. If that need to stop the boilers the temperature of inlet of the air preheater gas should be below 200℃。

If the rotor still remains in stop after taking the above measures as mentioned, the dampers of the gas inlet and the air outlet should be immediately closed, and also the same side draught fan should be closed. The boiler loads should be decreased to perform the operation. Even the boiler emergency shutdown shall be required.

5.9.3 Abnormal rising of bearing oil temperature

The lubricating oil circulation system will start up oil pumps automatically to perform circulation and cooling if bearing oil temperature exceeds 55℃. If oil temperatures can't go down due to oil leakage of the oil circulation system, oil quality deterioration or damage of bearing (s) itself, inspecting of the entire oil system, observing of the cooling water flow and temperature, oil flow indicators, pressure gages and oil levels in the bearing boxes, etc. should be performed. If the oil temperature still keeps increasing up to 70 ℃ without above troubles, the system will alarm. In case that the oil temperature exceeds 85 ℃, the air preheater shall be shut down immediately in accordance with operation steps as described before.

5.9.4 SECONDARY ELECTRIC MOTOR CAN NOT DRIVE ROTOR

There is a exceed clutch between secondary electric motor and speed-down case, which will appear fray because of its racing state, and can not bring along speed-down machine to rotate AH once fray exceed the limit. So should use handwheel with trail axis

of secondary electric motor to check capability of the secondary electric motor when check and repair boiler every time. Change the clutch frayed largely.

5.9.5 Air Preheater firing

5.9.5.1 Firing cause and judgment

Combustible matters, depositing on the heating elements of the air preheater, produced by boiler incomplete combustion will fire under the condition of the right temperature and the right amount of oxygen inside the air preheater, which is usually called as the secondary combustion. In case of the secondary combustion, it will burn out the air preheater.

The igniting point of the combustible matters on the heating elements is usually between 250℃-400℃ but it can reduce to 150 ℃ if the boiler operates with a higher percentage of oil firing.

5.9.5.2 Emergency measures in case of firing

a. Cut off fuel entering boiler for boiler emergency shutting down.；

b. Put fans out of service；

c. Open valves on pipelines of both upper and lower cleaning pipes ash hopper discharge ports under the air preheater, put fire fighting water into service；

d. Close the dampers of air preheater gas inlet and air outlet, if available. keep manholes closed；

e. Keep air preheater turning to ensure that the fire fighting water can be received by every part of the heating surface；

f. Close washing water valves after confirming that the fire has been put out. Come into the air preheater with fire hydrants to extinguish any residual fire sparks and begin to inspect；

g. Keep persons in guard to prevent refiring.

5.9.5.3 Measures for prevention from firing

a. Minimize times of starting-up and shutting-down.

b. Shorten boiler operation time at low loads at which a relatively high percentage of oil will be fired.

c. Maintain normal sootblowing and regular water washing.

d. Enhance monitoring of gas, air temperature indications, especially changes of gas and air temperatures in the upper part of the air preheater in the conditions of the heat retention of the boiler and the sudden stoppage of the air preheater.

5.10 Lubricating table

Parts and lubricating points	lubricating methods	Operation temp	Lubricating volume	Oil used	Lubricating period and notes
1. Air preheater main shaft bearings					
(1) Guide bearing	Oil bath +circulation	＜55℃	Approx. 30 litre	Industrial gear oil150＃	Renew oil once every 4000 operation hours
(2) Thrust bearing	Ditto	＜55℃	Approx. 500 litre	Ditto	Ditto
2. Bearing oil circulation system					
Oil pump motor	See maker's manual				
3. Rotor drive unit	See maker's manual				
4. Sootblower	See maker's manual				
5. Seal control system	See maker's manual				
6. Infrared fire alarming system	See maker's manual				

Chapter 6 Fuel system

6.1 System and equipment introduction

6.1.1 General

The main purpose of fuel electrical plant allocated fuel system:

1) Coal burning boiler ignited with supporting oil in start stage.

2) When boiler in low loading and using fault coal, stabilize the burning with fuel, and improve the combustion condition in furnace, avoid the abnormal flameout of boiler.

6.1.2 Physical character of fuel

As the following indexes to describe the physical character of fuel in industry standard:

1) viscosity： Fluid flowed by the forcing, among the fluid molecules or fluid groups, the internal friction, the value of viscosity, usually, are expressed with three methods: kinetic viscosity, movement viscosity, Engler viscosity.

Engler viscosity is mainly used for oil viscosity in engineering, the definition of Engler viscosity is on a certain oil temperature, the time ratio of the delivery time of 200 ml oil and the time that 200 ml distilled water with 20℃ flowing out of the Engler viscometer.

2) Solidifying point is used as an important index for liquidity of oil product. Diesel will have no liquidity when temperature dropping to a certain degree, slant the oil filling test tube for 45 degree, the temperature, at which the oil surface can maintain for 1 min without changing, is the solidifying point, the solidifying point is related to the paraffin content in oil, low paraffin content, low solidifying point; high paraffin content, high solidifying point.

3) flash point：For oil heated to a certain temperature, there is oil steam on the surface, when oil steam mixing with the air and reaching to a proportion, the mixture gas under the experimental condition will have instant flash flames ignited by naked flame, the lowest temperature at that moment is called flash point. The flash at the flash point is instant, as the evaporation rate of oil is slow，oil steam can not be

supplied timely. Flash point is the foreboding of accident.

4) ignition point：When fuel heated to a degree, the surface fuel steam molecule approaching saturation, mixing with the air, and naked fire will ignite it and keep on burning, temperature of this moment is called ignition point or inflammation point. Usually, the ignition point is 20℃~30℃higher than flash point.

5) self-ignition point：Fuel under the required heating condition, burning without approaching the outer fire source is called self-ignition; the lowest temperature for self-ignition is called self-ignition point.

6.1.3 Operating principle of oil burner atomization

Atomization methods for boiler oil burner usually can be classified into mechanical atomization and steam (air) atomization.

Mechanical atomization：see Fig 6-1，A simple mechanical atomization oil nozzle mainly composed by atomization disc, spinning disc, splitter vane. Step one, oil with pressure passes through the holes on the splitter vane, getting together in a circular groove; step two, the oil flows into the tangential groove on the spinning disc entering into central spire chamber. Splitter vane is used for distributing the oil flow of each tangential groove equally; tangential groove and spire chamber transfers the oil pressure into rotating momentum as well as making the oil gain corresponding rotating strength. The violently rotated oil flow passing through the atomization central hole outlet, with the influence of centrifugal force, overcomes the oil surface tension, altered into mist liquid drop, and formed into a taper shape atomization torch with a certain spread angle. In mechanical atomization nozzle, the diameter of atomization oil drop is determined by oil viscosity, pressure or the rotating strength that gained in the oil nozzle.

Steam atomization：Make use of the inner mixture of oil and atomized steam in the nozzle, the mixture creates pressure fall, volume increase at the outlet of nozzle; the oil is smashed into fog drop.

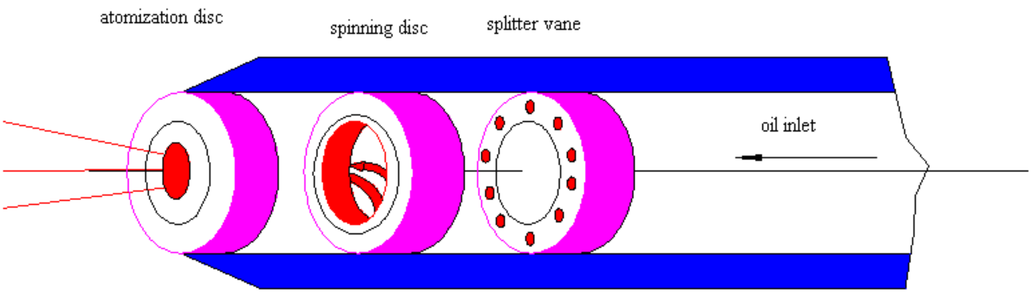


Fig 6-1 Mechanical atomization nozzle structure diagram

Air atomization：As shown in Fig 6-2, the fuel will be directly shattered by the high-speed jet of the compressed air to generate the flows of bubbles that is enclosed by oil film in the atomization chamber**;** when bubbles pass through the nozzle, the blast atomization will be produced, and then the oil will be changed into super-fine oil drop for combustion.

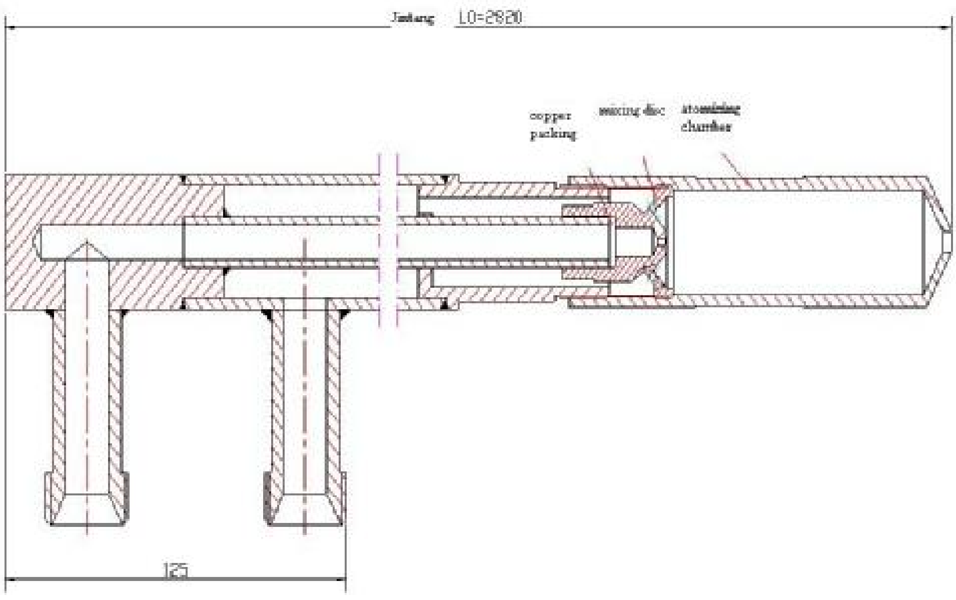


Fig 6-2 Air atomization nozzle construction diagram

6.1.4 High-energy igniter

High-energy igniter mainly utilizes the power exciter that producing high voltage providing the oil-gas mixture with the firing voltaic arc; it is mainly formed by spark rod,

flexible devices, cables, conduits etc.

Oil burner and ignition device start sequence:

1) Oil burner and ignition rod on ignition position in furnace;

2) Position confirmed; switch the multi-function tripping gate valve of oil burner into ignition position; make the oil enter into oil burner;

3) Power up the exciter, high voltage produced, spark rod creates sparks on the spark head;

4) At this moment, within the required 15s period, spark head ignites fuel gas flow with the frequency that 4 sparks/second.

5) When 30s' period is over, cut the circuit of exciter, spark rod quits automatically.

6) Every oil burner equipped with flame detector, ignition fulfilled will be indicated by symbol.

7) If ignition failed, no signal displayed, the oil burner and multi-function valve will have trip-free immediately to cut the oil supply. Find out the reasons for failure and repeat the procedures above.

6.2 Operation maintenance of fuel system

6.2.1 Check prior to operation of stokehold fuel system

1) Fire fighting equipments of stokehold are complete, in good condition; fire water system is in operation.

2) Fuel adjusting valve, tripping valve, oil burner feeding magnetic valve checked and qualified, action normal. Corner valve of each oil burner closed.

3) Steam blowing system in operation, pressure normal.

4) Check control steam source pressure for blowing steam to each oil burner, steam source valves open.

5) Check the position feedback display of oil corner valve.

6) Confirm the secondary air baffle opening degree of each oil burner.

6.2.2 Stokehold fuel system in operation

1) Confirm the operation of fuel pump and the stokehold fuel pressure.

2) Open stokehold feeding controller manual gate, switch on return oil magnetic valve manual gate rear and front.

3) Open the inlet return oil flow meter manual gate rear and front.

4) Open the pressure adjusting gate rear and front of each oil layer.

5) Open the feeding manual gate to each oil burner.

6) When the fuel bus bar leakage testing is over, blow for 5 minutes prior to furnace ignition, open the tripping valve of fuel bus bar, MFT relay restored.

7) Check the oil pressure set value of each layer and fuel automatic adjusting.

8) Check the burner oil pressure of each layer and fuel system, examine the leakage of systems.

9) Stokehold system in boiler operation shall maintain constantly operation to ensure engaging the oil burner for combustion supporting freely.

6.2.3 Stokehold fuel system splitting

Oil burners stopped completely and swept, shutdown fuel tripping valve and intercept valve rear and front, close return oil tripping valve intercept rear, close the feeding manual intercept gate of each oil burner.

6.2.4 Check prior to operation of oil burner

1) Check the operation of stokehold fuel system

2) Stokehold fuel pressure normal, blowing and baffling steam pressure normal

3) Flame check for the air cooling air pressure.

4) Fuel temperature in proper degree.

5) Fuel leakage testing qualified.

6.2.5 Conditions for oil burner in operation

1) Allowable layer ignition Pilot lamp lighting

2) Oil burner flame check in operation.

3) Oil burner corner valve closed

4) Proper fuel temperature

6.2.6 Operation maintenance

1) Oil burner in good operation condition or standby condition.

2) Switching off oil burner shall be in the complete exit position, or contact the maintainer to handle with.

3) Check the sealing of oil burner and stokehold fuel system.