清華大學
Tsinghua University

Design and operation of 600MW CFB boiler in China

Hairui Yang

Tsinghua University, China

Dongfang Boiler Group Co., Ltd

Shenhua Guoneng Energy Group co.ltd.

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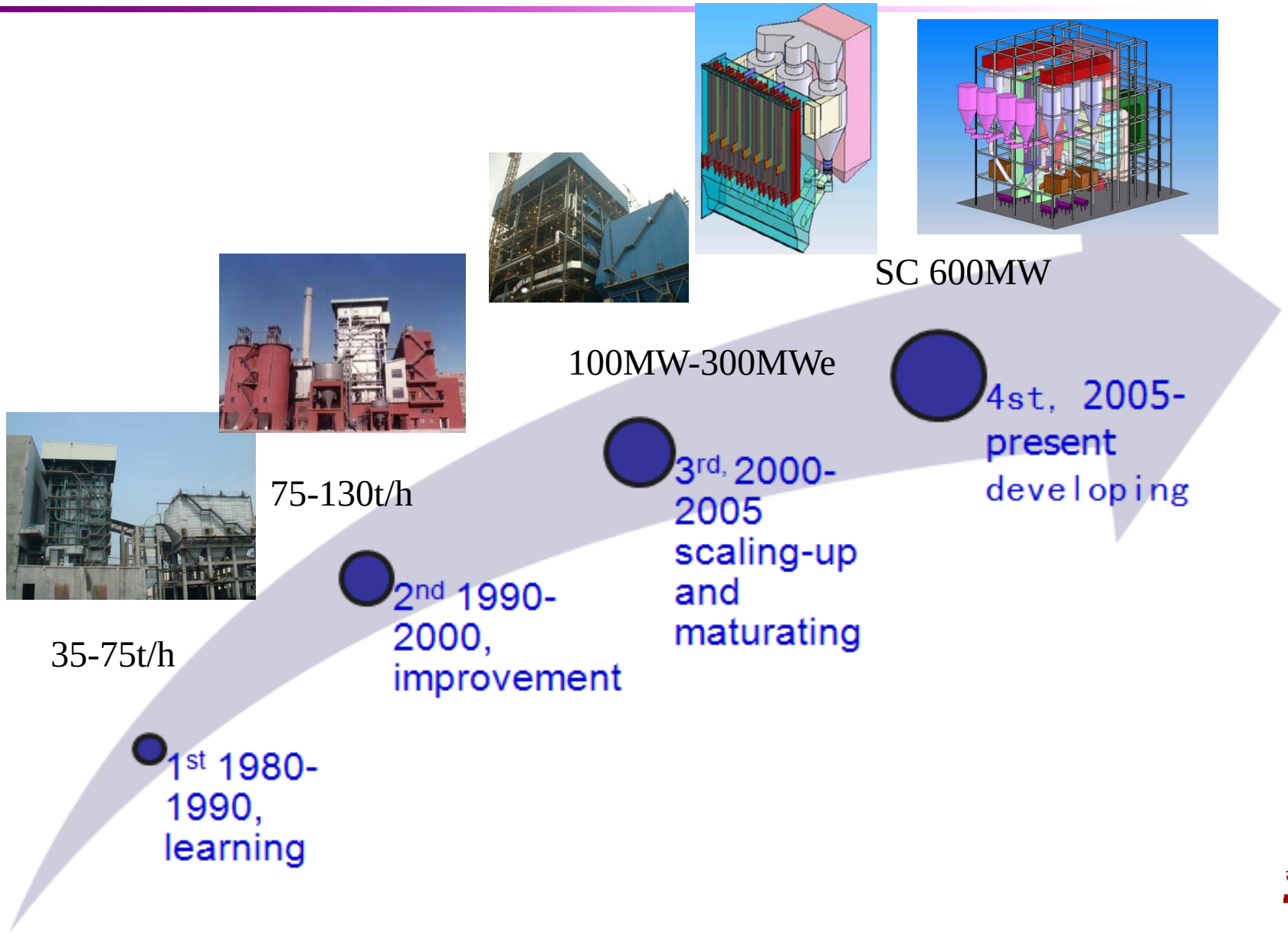
CFB-TH

History of the CFB in Tsinghua and China



Effect of steam parameters

Ultra-supercritical, dual loop reheat from 566°C to 720°C

$$\Delta\eta = 5\%$$

Ultra-supercritical, single loop reheat to 600°C

$$\Delta\eta = 4\%$$

supercritical, single loop reheat

$$\Delta\eta = 3\%$$

subcritical, single loop reheat

~30%

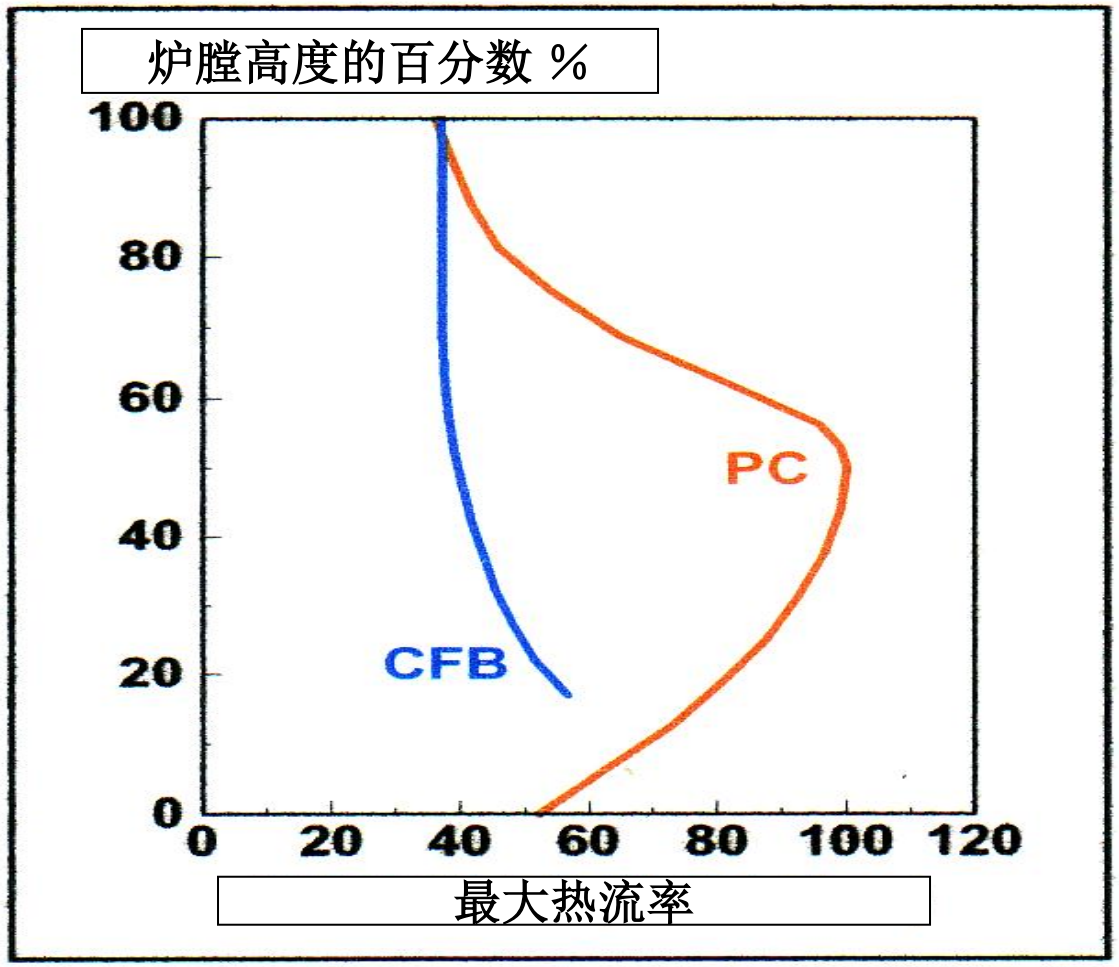
~20%

$$\eta = 37 \sim 38\%$$

T=25°C cooling water in the condenser

Saving Fuel

comparison of the heat flux along the boiler height between PC(red)and CFB(blue)



Features of heat flux in CFB

- **50% lower than that of the PC boiler, the highest mainly in the taped section covered with anti erosion layer**
- **The flow rate can be lower as 500－700 kg/m^2-s, much lower than that of PC boiler of >1000 kg/m^2-s**
- **Lower flow rate has the feature of nature circulation for Benson straight tube, i.e. flow rate increases with higher heat flux**
- **The temperature deviations decreases**
- **Smooth tube can be used**

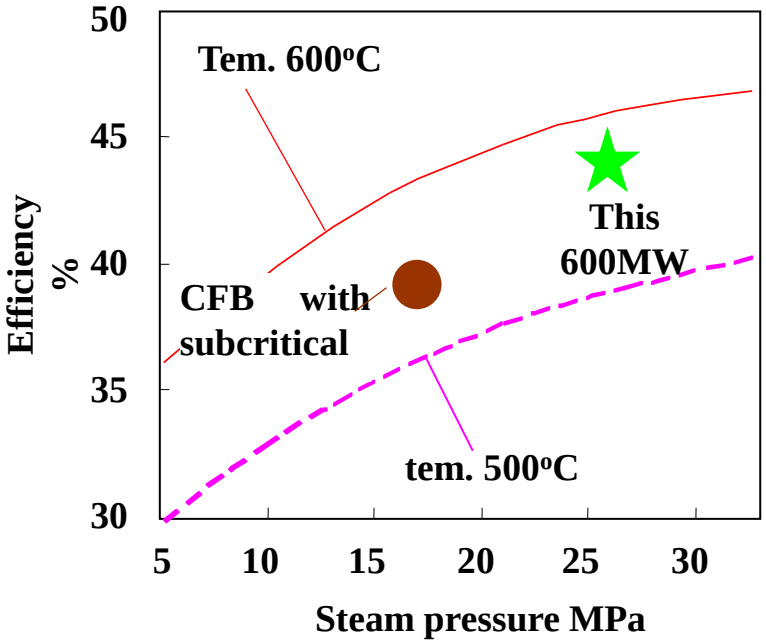
The advantage of supercritical parameters with CFB boiler

Schedule of the developing of 600 MW SCCFB

- **2003 fundamental studies**
- **2007,1,17 design approved**
- **2009,2,24 DBC contract signing**
- **2010,11,26 boiler erection**
- **2012,7,5 cold commissioning**
- **2012,12,30 hot commissioning**
- **2013,4, 14 passed 168 h test**

CFB combustion and supercritical steam cycle

- High generation Efficiency
- SCCFB as a technical route



Efficiency VS steam parameters

- Develops at the same time with FW and independently

10th five year plan （continue）：

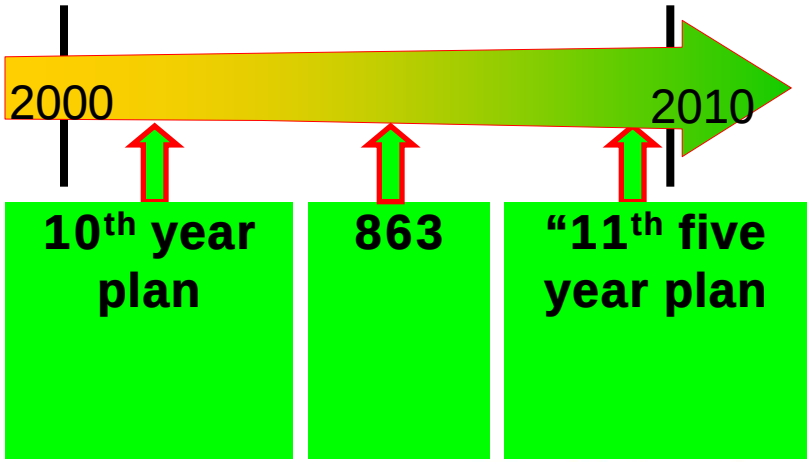
solve the feasibility study

“863”：

solve the Technical scheme and key parameter-heat flow density

11th five year plan：

key technology and project



Key technologies

Basic researches facing application

Key points for SCCFB boiler

- Flow **regimes in ultrahigh riser** **(1 PhD)**
- Feasibility of vertical tube **(1 PhD)**
- Maldistributon among multi cyclones **(1PhD +1M.S)**
- Stability of ultra-large bed **(1M.S)**
- Technical scheme **(1PhD +1M.S)**
- Hydrodynamic of low mass flow **(1PhD)**
- Dynamic model of boiler **(2PhD)**
- SCFB simulator **(1M.S)**
- Key auxiliaries **(2 M.S)**

Achievements

Basic and applied basic research

100 papers
50 patents

combination of theory and Practice

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Concept of 600 MW supercritical CFB suggested by Tsinghua

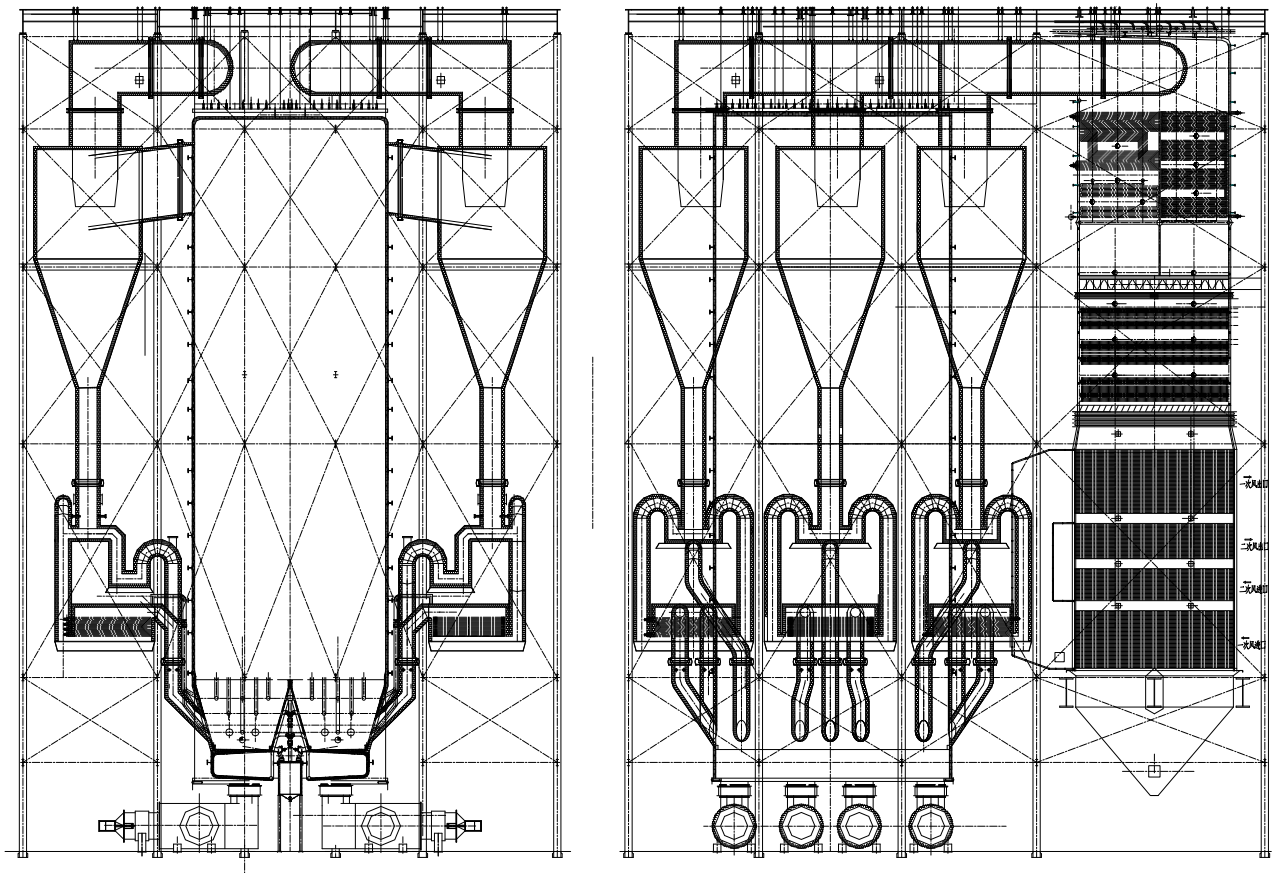
T shape

6 cyclone

6 EHE

Benson smooth tube furnace

Mass flux in tube can be lower as 800kg/m^2.s



In Design Phase

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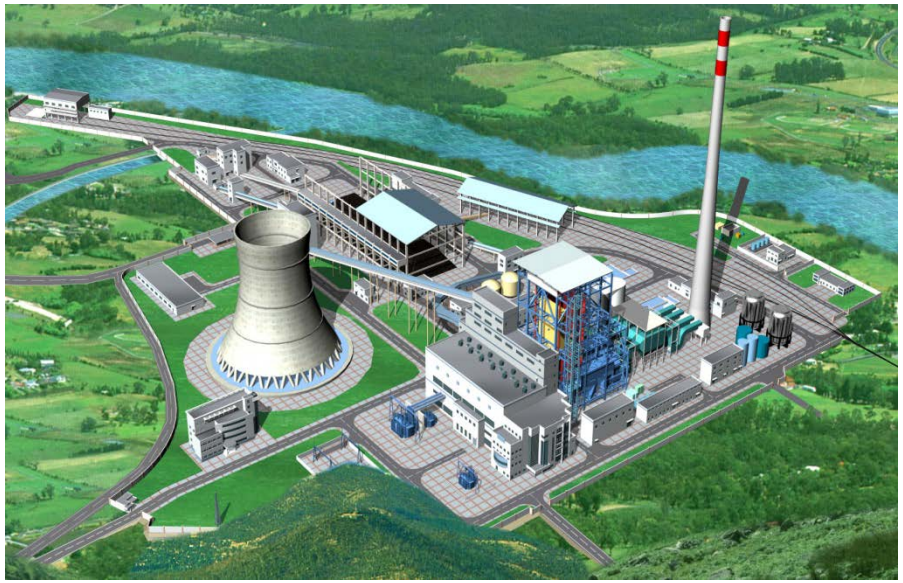
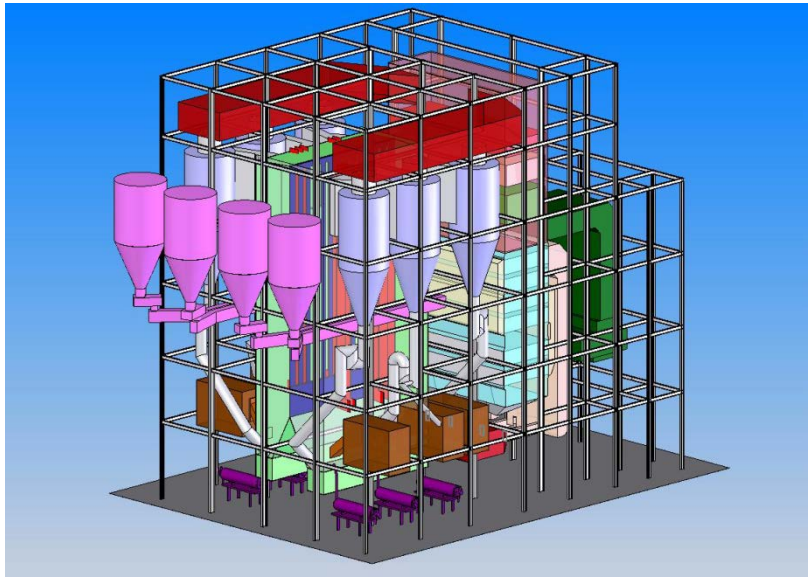
600MWe made by DEC in Baima





- high efficiency， economic-effective
- high availability, reliability
- low emission
- highly flexible in operation, turn-down ratio,
- low maintenance cost
- high fuel flexibility

Design coal properties and boiler parameters for the 600MWe SC-CFB

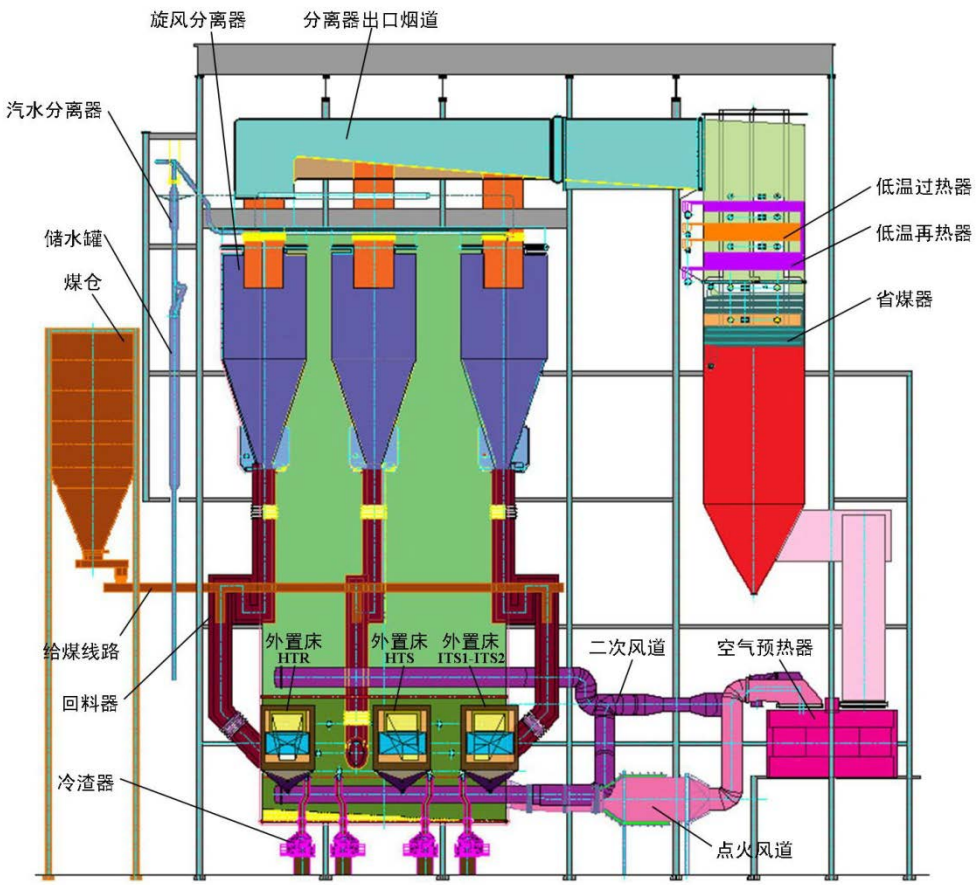
Design Coal Properties

Item	Unite	Value
Mar	%	**7.58**
A_{ar}	%	**43.82**
V_{daf}	%	**14.74**
$Q_{net,ar}$	kJ/kg	**15173**
C_{ar}	%	**41.08**
H_{ar}	%	**1.62**
O_{ar}	%	**2.06**
N_{ar}	%	**0.54**
S_{ar}	%	**3.3**

Design parameters of the boiler

Item	Unit	Value
Steam output (BMCR)	t/h	1900
Main steam pressure	MPa	25.4
Main steam Temperature	℃	571
Reheat steam flowrate	t/h	1568.2
Inlet/outlet pressure of reheated steam	MPa.a	4.58/4.43
Inlet/outlet temp. of reheated steam	℃	317/569
Feeding water Temp	℃	284

Design features of the 600MWe SC-CFB



Pant-leg, single face middle wall, even pressure wind box

Feeding coal in loop seal

Combined ignition

Ash drain from side wall, 8 roller ash cooler

6 cyclone, 6 EHE

Single second pass

4 regenerated air heaters with 4 sectors

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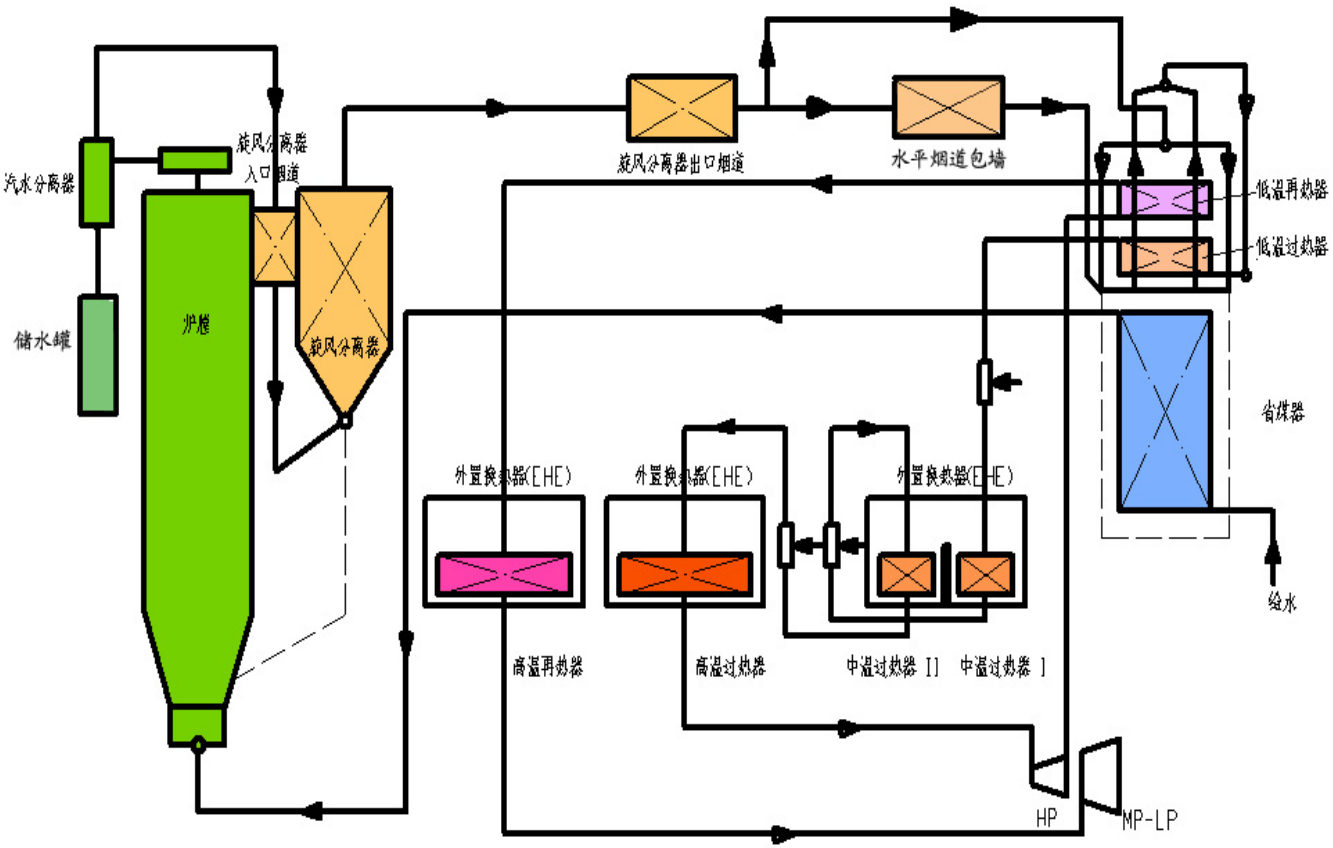
Water and steam system



Inlet of cyclone ⇒cyclone⇒outlet of cyclone⇒cover wall⇒hanging tubes⇒LTS⇒ 1st attem⇒ ITS1 ⇒2nd attem⇒ITS2 ⇒ 3rd attem⇒ HTS

controlled by the ratio of coal to water, and attemerator.

LTR→spray attemperator→HTR

controlled by the ash flow rate in EHE

The largest 600MW SCFB boiler pass the 168h test

- **8am,2013-4-14,the 600MW SCCFB boiler developed with TH technology passed the 168h test**
- **The operation parameters meet the design values and operates stably**
- **Such boiler with the largest capacity and highest parameters means TH CFB technology is among the advanced in the world**
- **Shenhua Baima**

During 168h test

Steam/water parameters at BECR loads

Item	Unit	606MW	604MW
Steam output	t/h	1735	1724
Main steam pressure	MPa	24.40	24.25
Main steam Temperature	℃	569	570
Reheat steam flowrate	t/h	1568.2	
outlet pressure of reheated steam	MPa.a	3.84	3.86
outlet temp. of reheated steam	℃	571	559
Feeding water Temp	℃	280	280

Zheng XS, Guo Q. et al. 2013

Outlet Temperatures of heating surfaces at BECR loads

Temperature	Unit	606MW	604MW
Outlet of the water wall	℃	403	400
Outlet of the middle wall	℃	423	427
Outlet of the LTS	℃	455	454
Outlet of the ITS1	℃	491	489
Outlet of the ITS1	℃	522	520
Outlet of the LTR	℃	480	477
Furnace temperature	℃	895	895.4

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Economic and emission Performance

item	Unit	value
Carbon content in fly ash	%	4.0-6.0
Carbon content in bottom ash	%	1.0-2.0
O2 in air pre-heator	%	3.5-4.0
Temperature of the flue gas	℃	130-135
SO2 (not modified)	Mg/Nm^3	320-360
Nox (not modified)	Mg/Nm^3	112-164
Boiler efficiency	%	91.8-92.3

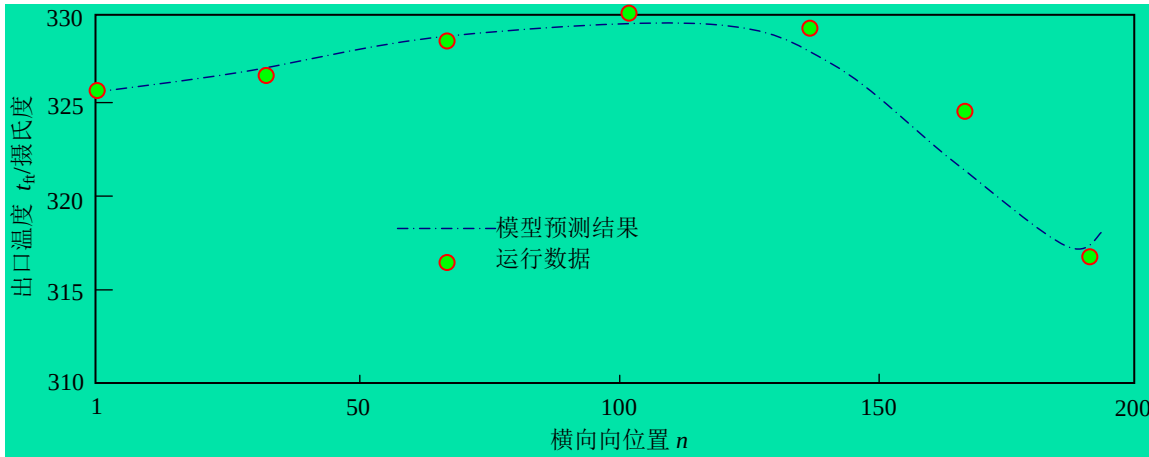
Zheng XS, Guo Q. et al. 2013

Performance data

- **Furnace tem.: operation and design <5℃**
- **Furnace outlet gas tem.: operation and design <10℃**
- **Flue gas tem.: operation and design <5℃**
- **Nox emission : <150mg/m^3**
- **Carbon content in fly ash : 3%~4%**

Safety data

- **Measured steam temperature distribution along the wall width meet the calculation, validating the fundamental researches on heat transfer**



Some problems in operation

1: damage of the ignition gun

2: coking in furnace

- Fan trip causing bed material collapse
- Bed material size is too coarse
- Coal feeding is not even

3: ash leakage in the EHE

Thanks for attention !