58th IEA_CFB meeting

Update of CFB research and development in China

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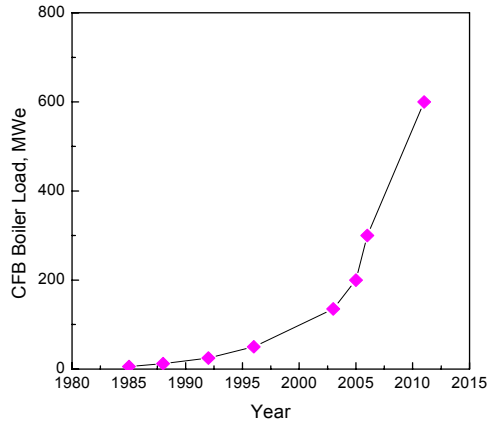
Marketing of CFB in China

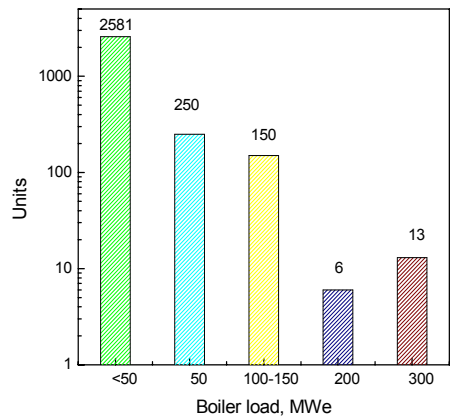
Total capacity: 63000MWe, occupying over 10% of coal fire power in China.

Total number of operating CFB boilers: around 3000.

During the Eleventh Five Year Plan (2007-2011), 50 units of 300MWe CFB boilers are to be built and more CFB boilers burning coal waste with total capacity of 2000MWe are under approval.



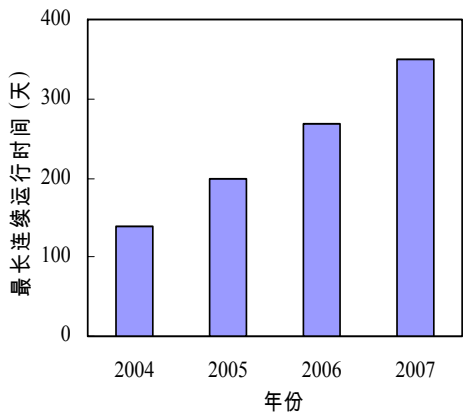
capacity developing of Chinese CFB



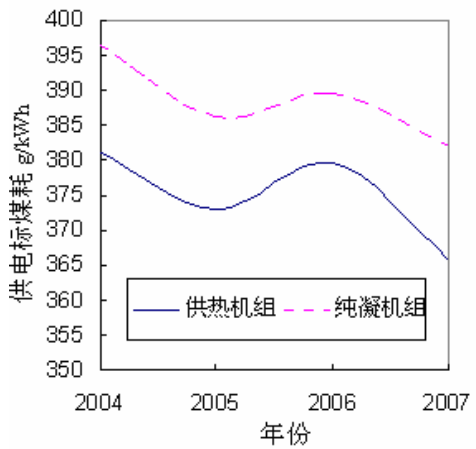
Unit number of CFB boiler in China

Performance of CFB in China

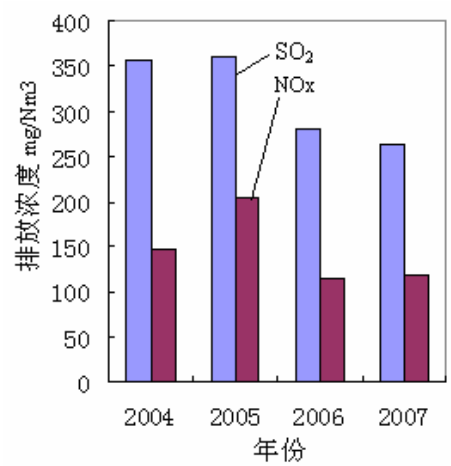
Operating performance is improving



Statistic of continue operating time for 135MWe CFB boiler



Statistic of fuel consumption of power generation for 135MWe CFB



SOx and NOx emission for 135MWe CFB

Research Activities and Results

Frame of research

- Gas –solid two phase flow in circulating fluidized bed
- Combustion in CFB
- Heat transfer in CFB furnace
- State Specification Design Theory of CFB boiler

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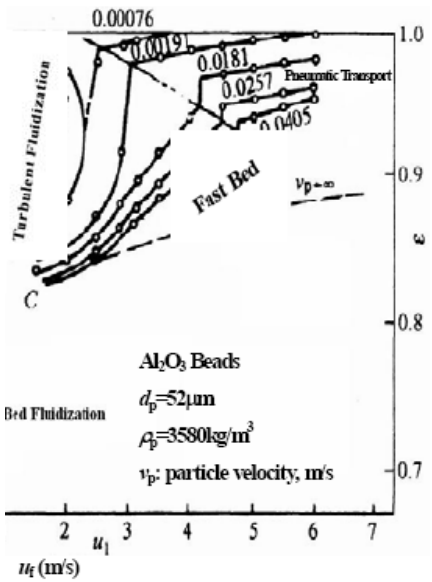
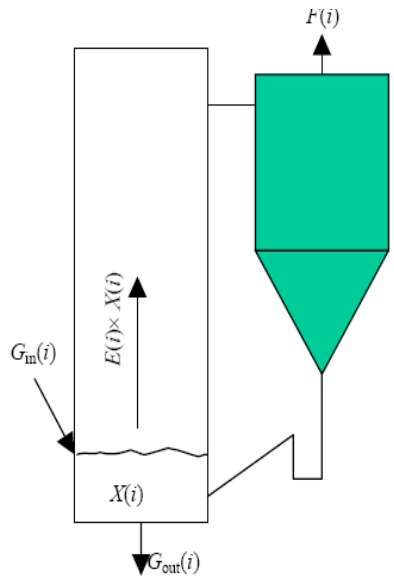
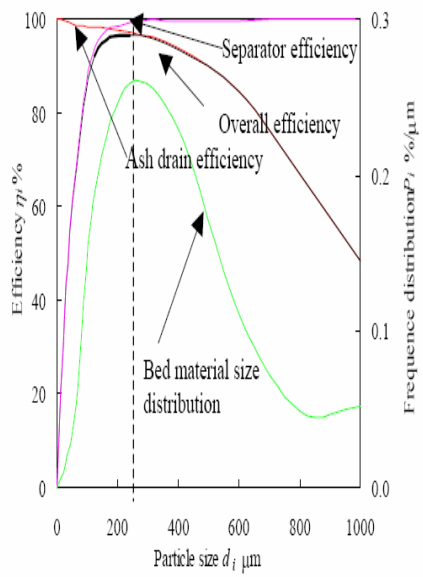
Gas –solid two phase flow in CFB

(1) Material balance in CFB loop

- Confirm a combined bubble bed with fast bed in CFB furnace.
- For fast bed, multi status corresponding to one gas velocity.
- Suggest the concept of multi size particle balance in the open circulating fluidized system. The balance only be depending on so called overall particle collection efficiency and input fuel ash size formation character that can be measured in lab. Test.

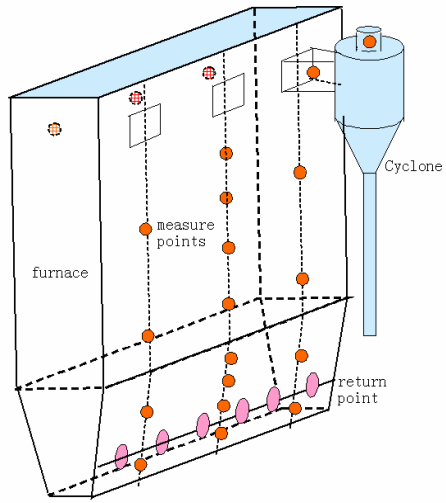




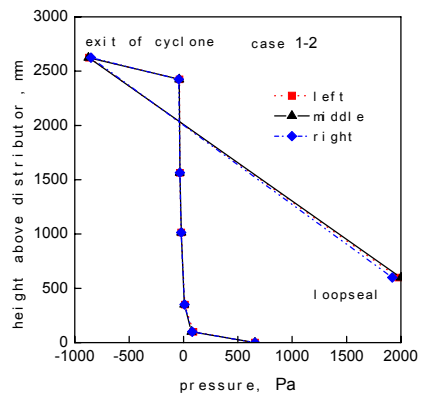


(2) Multi cyclone loop character of large CFB

- The results confirmed the polymorphism of flow pattern in multi cyclones.
- Experimental investigation was done to simulate the fluid dynamics in the 300MWe and 600MWe CFB boilers with multiple cyclones.
- In the furnace the lateral difference of the axial pressure profiles corresponding to the cyclone location is little, indicating that the transverse material concentration distribution in the furnace is unbiased.
- However, the solid flow rate and the material distribution in one loop could be remarkable different from the others.
- Under present experimental condition, the circulating rate in the middle loop is about 10% larger than that in the side loops.



Experimental facility



Pressure balance in CFB loop

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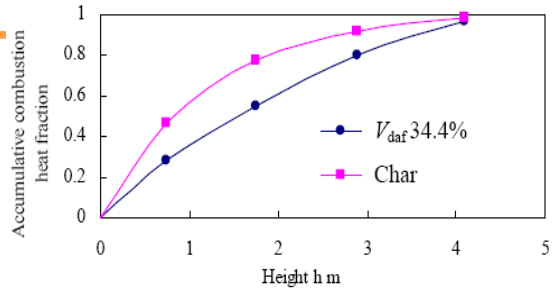
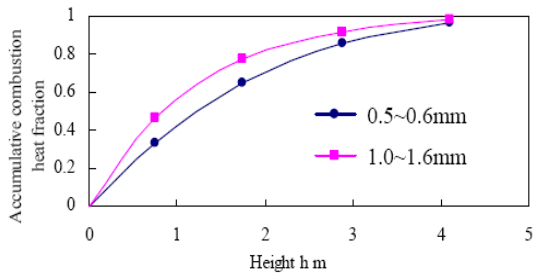
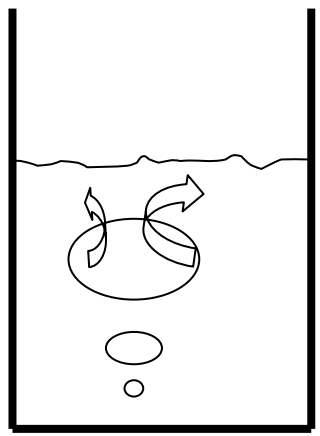
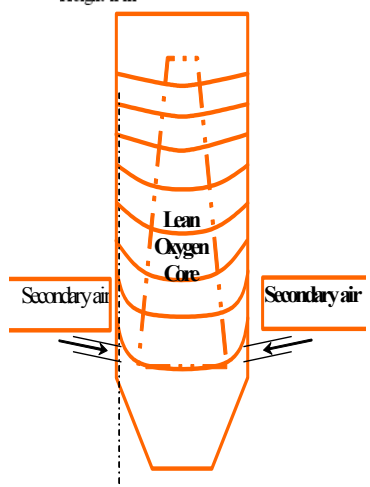
Combustion in CFB furnace

- Suggest the concept of one dimension heat release distribution along the height of furnace and develop a test system for measurement. Determine the impact of fuel size and character on the one dimension heat releasing.
- Confirm the the combustion in dense bed is an reduced condition but with rich O2 because of the gas diffusion between bubble phase and emulsion phase in dense bed.
- Find the reduce condition at the upper part of CFB furnace. Suggest the momentum of second air injection 。
- Investigation on the post combustion in cyclone









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Heat transfer in CFB furnace

- Following the idea by Prof. Leckner that the main mechanism of heat transfer in CFB furnace is particle convection and radiation . Develop tools to measure heat transfer coefficient in CFB furnace.
- Set up model and standard for heat transfer coefficient calculation in furnace.
- On site measure of two dimension heat transfer coefficient for thermal –hydro prediction of supercritical CFB design.

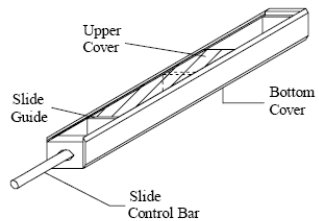
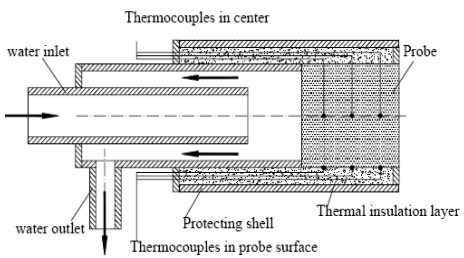
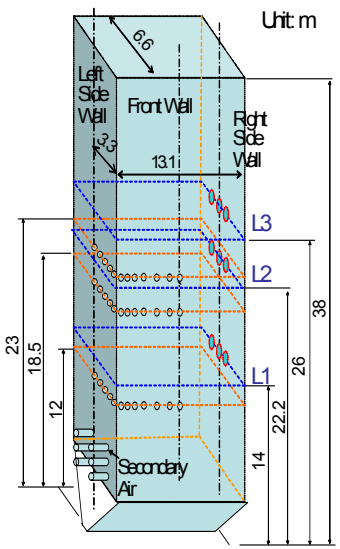


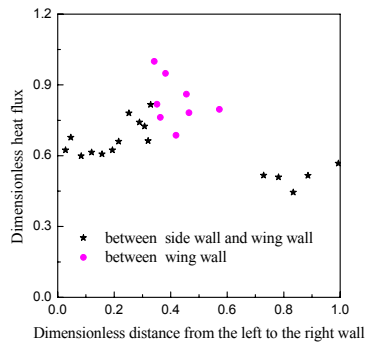
Figure 10 Sampling probe for bulk density

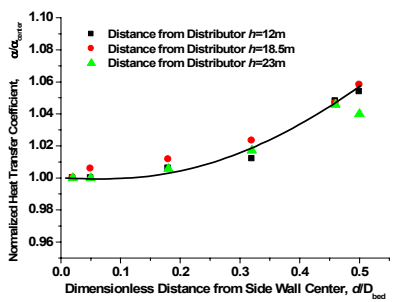


tools

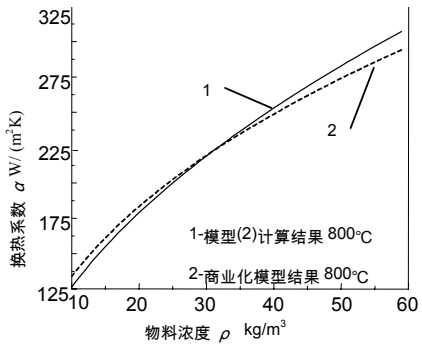


on site measure





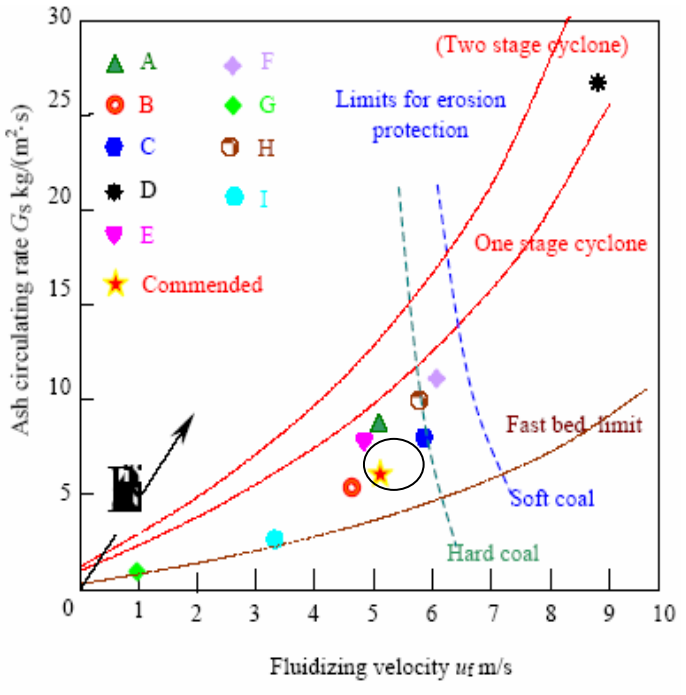
Heat transfer coefficient along horizontal



Heat transfer model

State Specification Design Theory of CFB boiler

- The CFB boiler with fast bed in the upper furnace can be operated at multiple states and each state is "specified" by Ug and Gs
- it is suggested that during the design of a CFB boiler, the state in fast bed regime is pre-selected. When the state is fixed, the heat transfer coefficient profile along the furnace height is also fixed.
- The operator should keep the CFB boiler operating around the pre-selected state by controlling the bed inventory.



CFB boiler fluidization status map

- A CFB boiler status selection map is developed for the design engineer.
- The map already be used to design CFB for Chinese coal, also used to relocate the status of some foreign CFB technologies to improve their performance.

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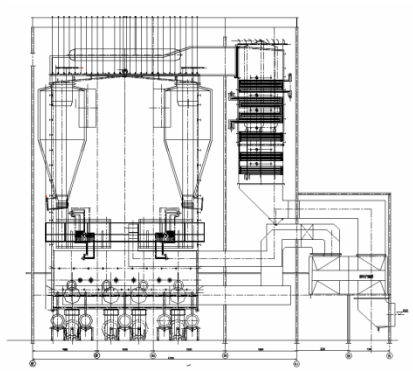
Challenges and Near-future Developments

If CFB want to stand up in utility world, it has to be competitive in three aspects:

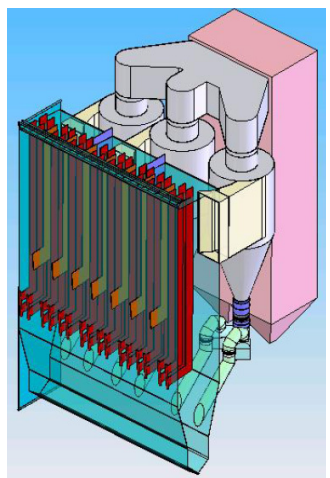
- (1) Power generation efficiency
- (2) De-SOx effectiveness,
- (3) Availability.

Capacity Scaling up for Efficiency Improvement

- The successful of Alstom 300MW subcritical CFB gave Chinese power sector confidence for subcritical CFB(17.5MPa,540/540) which gain 5% generation efficiency improve compare with 200MW reheat CFB(12.7MPa, 535/535) .



- China developed his own 300MW subcritical CFB for big market. Besides, a simplify process of 300MW CFB with single furnace and without EHE was practiced , that save more auxiliary power. It was welcomed and got more than 40 contracts.



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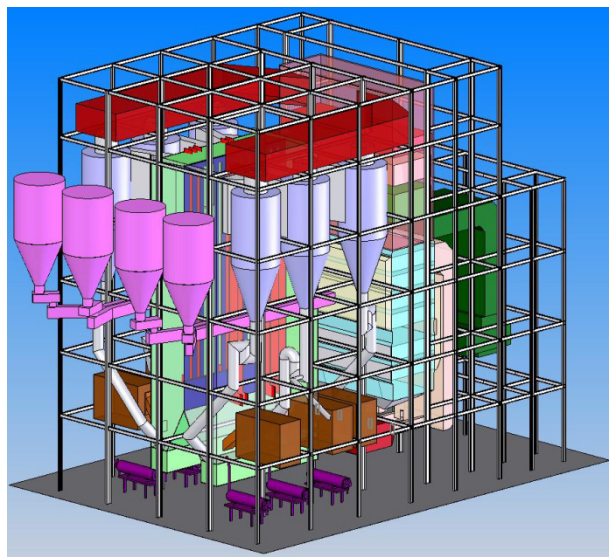
Supercritical CFB

- Research on supercritical CFB was started in 2003. A demonstration of 600MWe supercritical CFB was initiating in 2006 supported by government.

- The first demonstration in Baima was approved in 2008, that shall be commissioned in 2011

Steam T: 571℃/569℃
Steam P : 25.4MPa
Steam Flow: 1900t/h ,
Boiler efficiency: 92%
SO_2 : <300mg/Nm3 ,
NOx: <200mg/Nm3 ,
Generation efficiency: 42%



Schematic of boiler

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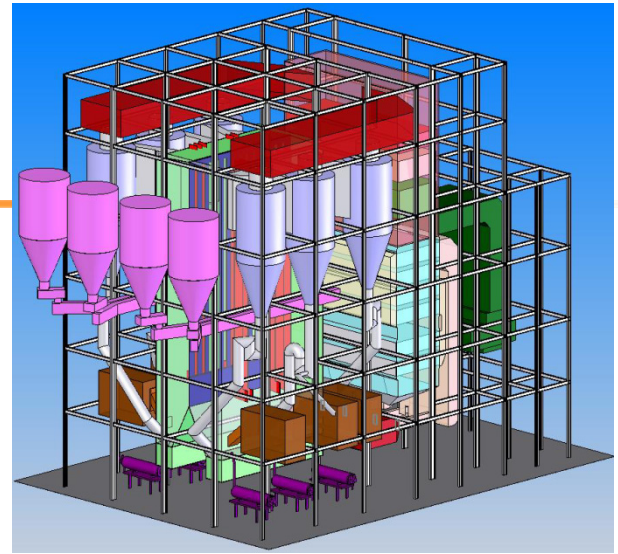
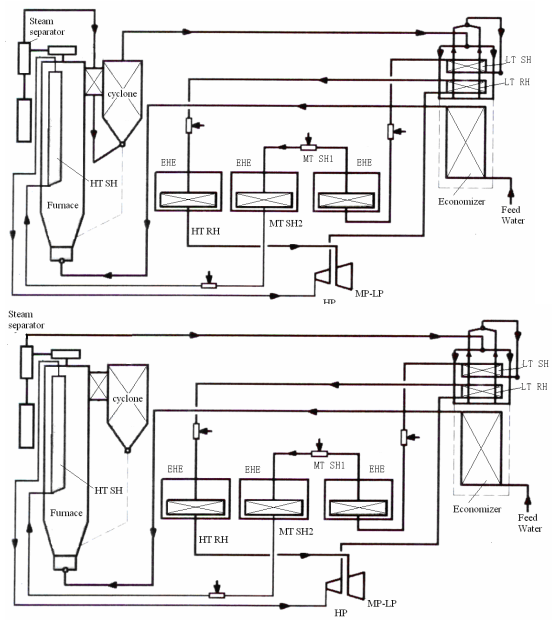
Feature:

- Benson vertical tube water membrane, mass flow 800kg/M^2 S
- Twin furnace (with total cross section 15x28m2 and 55 m height) divided by a partition water wall .
- Six cyclones with inner diameter 9m.
- six external heat exchanger (EHE).
- In furnace superheater panels
- The LT SH and LT RH in second pass
- The HT RH , the MT SH located in EHEs.
- There are two options for the cyclone selection – steam cooled and insulated .
- Water jacketed rotary ash cooler is used bed ash 2011.

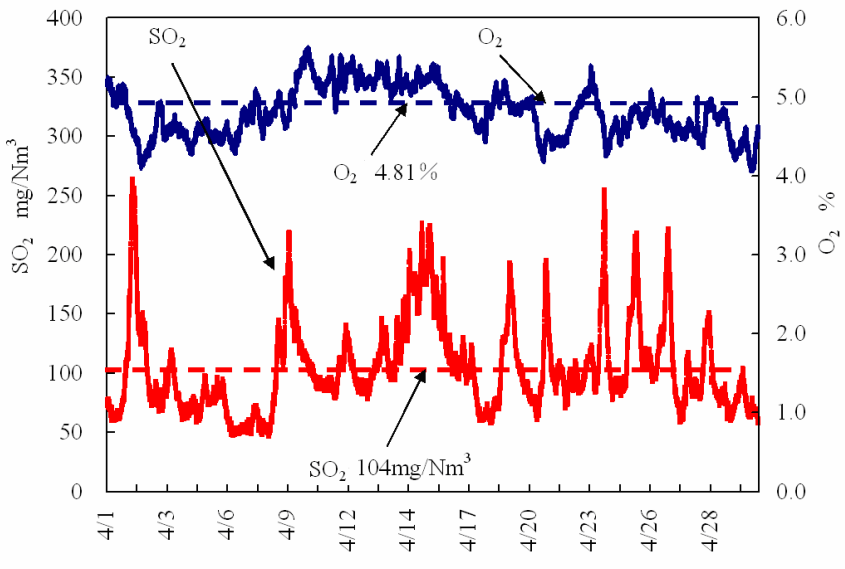


Schematic of boiler



SO_2 Removal in CFB Boiler

- The new SO2 emission regulation for coal fire power are becoming more stricter (<400mg/Nm3)
- Chinese CFB has never equipped qualify de-SOx system and no more experience on in-furnace de-SOx
- Recent efforts got satisfied results.
  CFB de-SOx cost: ￥0.008/kWh
  FGD de-Sox cost: ￥0.025/kWh.
- The compensation for de-SOx from Power Grid is ￥0.015/KWh.

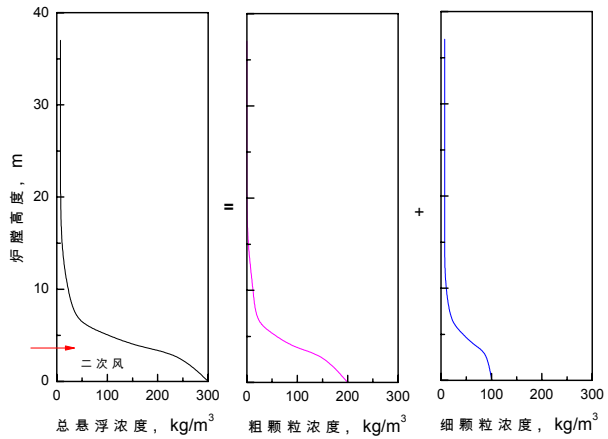


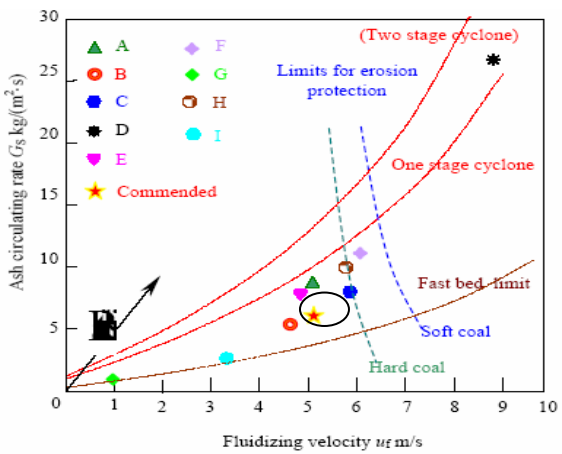
SO2 emission record for a 135MW CFB boiler in Huasheng Power after retrofitting. The average SOx emission over one month operation was 104mg/Nm3 when Ca/S=2.2, burning a coal with sulfur content of 2.11%.

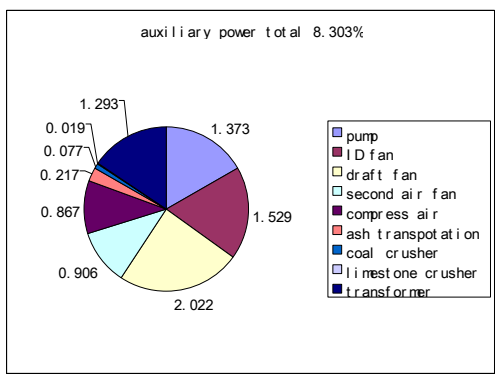
Energy Saving CFB Process

- Based on the State Specification Design Theory, Tsinghua University proposed a novel CFB technology by reconstructing the fluidization state in the furnace by adjusting the bed quality so as to decrease the bed inventory.

- It is expected to decrease the draft fan power and erosion in furnace.







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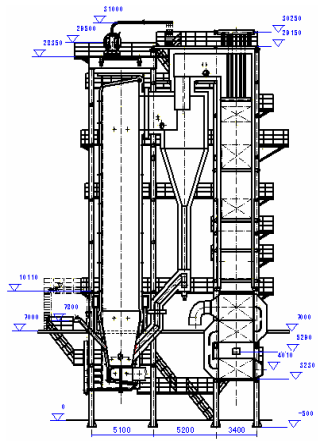
First practice for energy saving CFB process

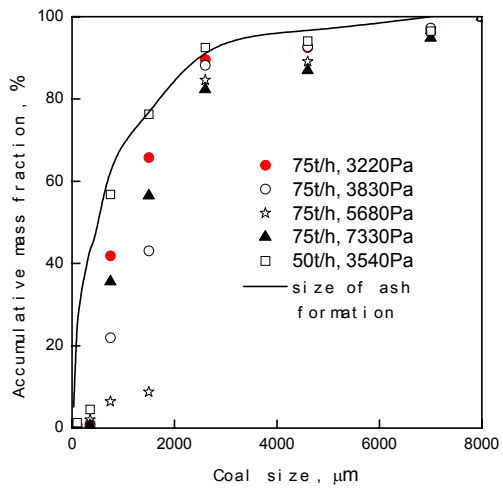
- The first test was done in a 75T/h CFB burning coal washing waste with heating value 3500Kcal/Kg. cyclone and loop seal were carefully designed for quality of material balance.

- Bed inventory was selected from 3.2-7.5KPa for full load operation.



Schematic of tested boiler

Overview of the tested boiler



Size distribution of feeding coal

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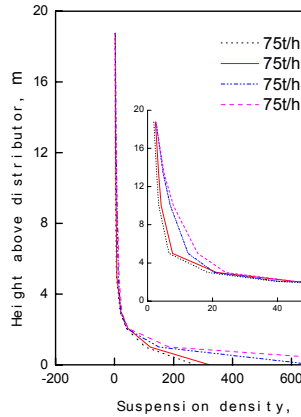
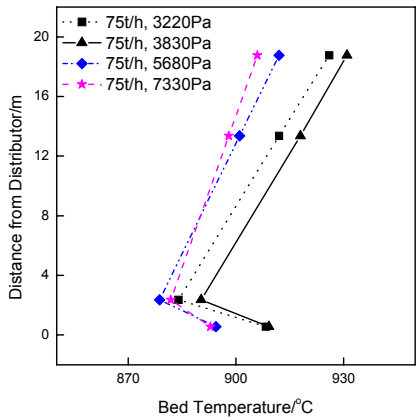
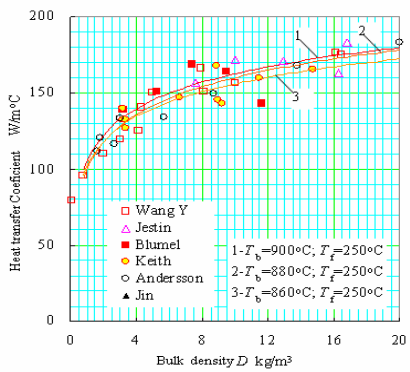
Results

- The boiler could reach full load even bed inventory was just 3.22KPa.
- As decreasing bed inventory, the dense bed was shrinking
- From bed inventory 7.5KPa to 3.22Pa, furnace temperature increased 170C.
- Clearly, the impact of suspension density on heat transfer is less. (need 5% heating surface more)
- One year operation for three units boilers save 5M KWh electricity, and no obvious erosion in furnace
- Technology already used for tens of CFB covering 15-50MWe and burning lignite ,bituminous and anthracite. Process patent is approved.
- Hope energy saving CFB process can compete with PC + FGD







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Biomass coal co-combustion

Demonstration of biomass CFB was initiated 5 years ago.
Steam parameter is 400-450C
Two types of superheater EHE or in second pass

Oxygen fuel CFB

Southeast University is leading the research
The pilot was built in the laboratory

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Chemical Looping

Chemical loop is in the stage of fundamental.
Many researchers are getting funding from the State Science Foundation.
No pilot or demonstration is built.

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Conclusion

- CFB boilers already dominate co-generation and entering utility in China.
- Chinese researchers and engineers accumulate more and more experience on the design theory, manufacturing and maintenance of CFB boiler.
- However, challenges and problems still remain, such as availability, power generation efficiency, and SO_2 capture.
- Continues efforts are making to improve the CFB technology . Besides the new topics are initiating, such as Oxgen-fuel and biomass .

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