MULTI FUEL CFB BOILER SIMULATOR

SYSTEM DESCRIPTION

SUPERHEATER STEAM SYSTEM
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1 GENERAL

After leaving the drum the saturated steam is led to the solids separator, cros over duct, convection cage walls and superheater I to IV, which dry and superheat the saturated steam. Superheater I is located in the back pass and superheater II after SH I. SH II is similar construction to superheater I.

Final superheating takes place in superheater III and IV, which are Intrex type and located in the return legs of the boiler.

It is necessary to cool the superheated steam so that full superheat can be obtained at various loads. This is done by means of desuperheater located in the interconnecting piping between the superheaters. Feed water is sprayed into the steam to cool it. The temperature after the desuperheater is used to regulate the spray water control valve. Desuperheaters are located in connecting pipes between superheaters.

Note, that the feed water is converted into steam and this cooling does not constitute a loss in efficiency. It is important, that the feed water is pure to prevent scaling of the superheaters and carry over of impurities with the steam to the turbine. For this reason it is also important that chemical dosing of non vaporating chemicals to the feed water takes place after the spray water take off. Vaporating oxygen scavengers can be dosed before because, they decomposes to a gaseous form and does not cause scaling.

Following superheater IV the steam enters the main steam pipe line. The final steam temperature is regulated by desuperheater and is kept constant.

There is two hydraulically operated 50 % by pass reduction valves from main steam line to cold reheat line. Two 50 % safety valves are located in hot reheat line. Reheat line safety valves also work as start up valves of the boiler.

By pass reduction valves have hydraulic control function and safety function which take place, if steam pressure in steam drum or in main steam line rises higher than pre set values in control logic cabinet. To the hot reheat line located safety valves are similar by action than HP-reduction stations, but follow only reheat line steam pressure and discharge steam to the atmosphere through silencers.
2 DESIGN DATA

2.1 Main steam values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure</td>
<td>bar</td>
<td>169</td>
</tr>
<tr>
<td>Flow</td>
<td>kg/s</td>
<td>113</td>
</tr>
<tr>
<td>Temperature</td>
<td>°C</td>
<td>563</td>
</tr>
</tbody>
</table>

2.2 Pressure drops

- High pressure side:
  - Feed water pipe to main steam pipe: bar ~ 22.5
  - Drum to main steam pipe: bar ~ 21
  - Cold reheat to main reheat pipe: bar ~ 4

2.3 Steam temp. control range

Steam temperature is controlled to 563 °C.

3 EQUIPMENT DATA

3.1 Compact separator walls

Separator consists of flat walls, which are normal membrane steam-cooled panels that are constructed by automatic welding machines. The walls are combined as part of the same water system used in the furnace enclosure walls.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td></td>
<td>15Mo3</td>
</tr>
<tr>
<td>Size</td>
<td>mm</td>
<td>44.5 x 5.6</td>
</tr>
<tr>
<td>Spacing</td>
<td>mm</td>
<td>104</td>
</tr>
<tr>
<td>Fins</td>
<td>mm</td>
<td>59.5 x 6</td>
</tr>
</tbody>
</table>
3.2 Separator headers

- Side wall inlet headers
  - Material: 15Mo3
  - Size: mm 219,1 x 40

- Front and rear wall inlet headers
  - Material: 15Mo3
  - Size: mm 219,1 x 40

- Outlet headers
  - Material: 15Mo3
  - Size: mm 219,1 x 40

3.3 Superheaters

The boiler is equipped with four superheaters. Superheater I is counter current flow type and superheater II is parallel flow type. Both are in the back pass. Superheaters III and IV are Intrex type superheaters located in bottom of the return legs. Superheaters are connected according to the Steam Diagram. The superheater banks are arranged to permit expansion.

The superheaters are designed to give a good heat transfer from flue gases to steam while avoiding excessive tube metal temperatures and excessive fouling from the ash of the fuel.

The superheater headers, tubes and supports are designed of suitable materials and construction to accommodate the steam temperature under the conditions of the various components.

Superheater I
- Tube type: bare tube
- Arrangement: in line
- Tube size: mm 38,0 x 5,0
- Materials: 7CrMoVTiB1010

Superheater II
- Tube type: bare tube
- Arrangement: in line
- Tube size: mm 38,0 x 5,0
- Materials: 7CrMoVTiB1010
3.4 Superheater headers

**Superheater I**
- Inlet header
  - Size \( \text{mm} \) 323,9 x 40,0
  - Material 13CrMo44
- Outlet header
  - Size \( \text{mm} \) 355,6 x 40,0
  - Material X10CrMoVNb91

**Superheater II**
- Inlet header
  - Size \( \text{mm} \) 323,9 x 36,0
  - Material 10CrMo910
- Outlet header
  - Size \( \text{mm} \) 355,6 x 40,0
  - Material X10CrMoVNb91

**Superheater III**
- Inlet header
  - Size \( \text{mm} \) 355,6 x 40,0
  - Material X10CrMoVNb91
- Outlet header
  - Size \( \text{mm} \) 406,4 x 65,0
  - Material X10CrMoVNb91

**Superheater IV**
- Inlet header
  - Size \( \text{mm} \) 406,4 x 65,0
  - Material X10CrMoVNb91
- Outlet header
  - Size \( \text{mm} \) 406,4 x 65,0
  - Material X10CrMoVNb91
3.5 Desuperheaters

System have three spray type desuperheaters for controlling of the steam temperature. Feedwater shall be used for spraying.

**Desuperheater I**
- Size: mm 323,9 x 40,0
- Material: X10CrMoVNb91

**Desuperheater II**
- Size: mm 323,9 x 40,0
- Material: X10CrMoVNb91

**Desuperheater III**
- Size: mm 323,9 x 50,0
- Material: X10CrMoVNb91

3.6 Valves for desuperheaters

Main line close valve
- Manufacturer: KSB
- Type: GT
- Size: DN 80
- Actuator: Automatic

Desuperheater I / II spray water hand valves
-Manufacturer: KSB
-Type: GL
-Size: DN 32

Desuperheater III spray water hand valve
- Manufacturer: KSB
-Type: GL
-Size: DN 40
Desuperheater I / II spray water motor valves  S1 LAE30/31 AA101
- Manufacturer  KSB
- Type  GL
- Size  DN  40
- Actuator  Automatic

Desuperheater I / II spray water control valve  S1 LAE10/20 AA201
- Manufacturer  KSB
- Type  CV
- Size  DN  32
- Actuator  Automatic

Desuperheater III spray water control valve  S1 LAE30 AA201
- Manufacturer  KSB
- Type  CV
- Size  DN  40
- Actuator  Automatic

Flow meter desuperheater I /II  S1 LAE10/20 CF201
- Manufacturer  Flowhow
- Type  ISA-Nozzle
- Size  mm  Ø42,4 x 6,3

Flow meter desuperheater III  S1 LAE30 CF201
- Manufacturer  Flowhow
- Type  ISA-Nozzle
- Size  mm  Ø48,3 x 7,1
### 3.7 HP bypass stations

The function of the HP bypass stations is to work as safety device for the boiler and main steam piping. The capacity of the HP bypass stations is the same as the maximum steam generation capacity of the boiler. The safety function pressure impulses are taken from the boiler drum (1 pc.) and main steam pipe (2 pcs.). The HP bypass stations are equipped with a control function acting at lower pressure than the safety function. The temperature after the HP bypass stations is controlled to 400 °C. The HP bypass stations will also be used during start-up and house load operation of the power plant.

<table>
<thead>
<tr>
<th>Number of units</th>
<th>%</th>
<th>Capacity (main steam)</th>
<th>kg/s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2 x 50</td>
<td>57,5</td>
</tr>
</tbody>
</table>

**Pressure set values:**
- Mechanical design pressure: 183 bar(g)
- Safety function (main steam pipe): 180 bar(g)*
- Safety function (boiler steam drum): 200 bar(g)*
- Quick opening function set pressure: 177 bar(g)*
- Control function set pressure: 175 bar(g)*
- Normal operating pressure: 169 bar(g)

*) Operating pressure set value + 4…6 bar. To be checked during commissioning.

### 3.8 Main steam valve

Manufacturer: Persta  
Type: Gate  
Size: DN 350  
Actuator: Automatic

**S1 LBA10 AA101**

### 3.9 Main steam by-pass valve

Manufacturer: Persta  
Type: Globe  
Size: DN 25  
Actuator: Automatic

**S1 LBA10 AA101**

### 3.10 Main steam flow meter

Manufacturer: Flowhow  
Type: Venturinozzle  
Size: mm Φ 273 x 28

**S1 LBA10 CF201**
3.11 Silencer

Manufacturer   Foster Wheeler
Material       Stainless steel

4 AUTOMATION AND INSTRUMENTATION

In this section automation is explained only basic level and more detailed descriptions can be found in Automation Descriptions.

4.1 Control principles

There are four superheaters in the superheating system, which raise the steam temperature. There are three sprayings between superheaters and respectively to control steam temperatures. The main temperature after SH IV will be controlled by the spraying between III. and IV. superheaters.

Sudden changes in fuel feed and steam flow have a compensating effect on controls before they affect steam temperature. Same kind of compensation effect is from the temperature before sprayings. Spraying water is taken from feed water line before the feed water control valve.

4.2 Main steam pressure control

When the turbine is not in operation, boiler main steam pressure is controlled by HP-bypass valves. HP-bypass controller maintains the main steam pressure by operating the both HP-bypass valves simultaneously.

Note: HP–bypass valves operate always in parallel.

Sudden changes in steam flow corrects the control before steam pressure changes.
5 OPERATION

5.1 Preliminary checks prior to start-up

Action by Control room operator and Auxiliary Operator

Verify that:
- Local boiler drum water sight glasses and drum level indicator shows the same
- Chemical feed system and sampling system are available
- Superheater and drum vent valves open
- Main steam line and SH/RH drain valves open
- Start-up valve open 100 %, if boiler is pressureless.
  If boiler has a pressure, set start up valve(s) to position of a minimum steam flow
  required to cool superheaters.
- Saturated steam sampling valves open
- Desuperheating/spray water line check valves are open
- Desuperheating control valves are operative
- All by-pass reduction valves and start-up/safety valves are in proper operating
  conditions.

Other system are also ready for start up of the boiler as for an example:
- Blow down tank and continuous blow down systems is ready to take in operation.
  All measurements and equipment of these systems are operative.
- Condensate system (condenser, pumps) is ready to take in operation. All measure-
  ments and equipment of these systems are operative. Cooling water system has been
  taken in operation. All measurements & equipment of these systems are operative.
- Make-up water system has been taken in operation. Make up water tank should
  filled full and feed water tank to its normal water level.
- Feed water system has been taken in operation – all measurements and equipment
  of this system are operative. All hand valves direction drum as well as pressure in-
  dicators are opened. Drains are needed to be closed.
- Feed water pump(s) are ready to take in operation & measurements are in operation.

Action by Auxiliary Operator

Walk down the boiler to verify that:
- Boiler drum access doors are closed
- All boiler flue gas side (combustion chamber, drop leg, separator, air heater, economiser,
  convection pass, superheater area, windbox) doors are closed and no inconvenient
  material or humans are inside of boiler
- All fan access doors are closed
- DeSOx system doors are closed
- Check for any leaks before proceeding.
5.2 Start-up

- Starting a boiler with no pressure and a turbine with metal temperatures below 200 °C is considered a cold start-up.
- When igniting the first burner, open the start-up valve to 30…100 % to maintain a flow through the superheaters.
- During boiler warm up, superheater/reheater flue gas temperatures must be limited to the maximum allowable superheater metal temperature.
- During boiler warm up, the bottom blow down and continuous blow down systems must be in service in case the boiler drum level goes high.
- During boiler warm up, the feed water system must be in service to supply make up water as required.
- Open boiler and separator drain valves for ½…1 minute each every 30 minutes until boiler pressure reaches 5…15 bar. It is denied to open these valves after 35 bar.

Note: Avoid increasing fuel flow at too fast a rate, since any excess steam is exhausted to atmosphere through the start-up valve and so wasted.

- When boiler pressure reaches 1.0 – 1.5 bar, close the boiler drum vent valves. Superheater and main/reheat steam line vent valves should be closed gradually, and at the pressure of 1.5 – 2.5 bar closed fully.
- Leave superheater drain valves partly open until boiler pressure reaches 8…12 bar, then close drains fully (when it can be ensured that steam is at least 20 °C superheated).
- Monitor boiler water chemistry continuously. If needed, increase blow down.
- During pressure raising, the position of the start-up valve is kept open so much, that superheater temperatures will remain under max. See material temperature curve, temperature increase app. 70 °C/h.
- After the start-up valves close, adjust main steam controller to match the turbine requirements, while increasing the boiler load.

5.3 Normal operation

After the start-up valves close, adjust main steam controller to match the turbine requirements increases the boiler load. In normal operation the boiler fuel control set point is main steam pressure and fuel flow is varied to maintain the set point, set by operator, operating the controller in Auto-mode.

- Monitor the superheaters material temp.s. See also superheaters temp. diagram.
- Check, that spray water controls work.
- Check, that safety valves work, when boiler pressure >max.
- Monitor the steam temp.
- Monitor the steam pressure.
- When the flue gas temp. is > 300 °C, there must be steam flow through the superheaters cool them.
5.4 Shut down

Shut down the boiler and check that spray water valves does not leaking.

5.5 Operating Disturbances

5.5.1 High Steam Temperatures

High steam temperatures can be caused by insufficient spray water due to a faulty control valve or plugging due to poor feed water quality. The cause should be traced and rectified. It is possible to use the manual by-pass valve until the control valve is fixed.

5.5.2 Tube leakage

– If a major leak occurs - burst of a tube - during operation, the combustion chamber pressure may rise due to the increase in flow caused by the sudden evaporation to steam.

– Should such a burst occur the ID fan flow should be increased and fuel flow stopped. At the same time steps should be taken to reduce the boiler pressure immediately with the start-up (or turbine by-pass) valve.

– Feed water should be brought to the boiler so, that the boiler parts do not overheat and only stopped when the flue gas temperatures have dropped below 400 °C. Keep the drum level at minimum.

– If the water level has been completely lost, do not bring cold feed water to a hot drum max. allowed difference ~ 50 °C. Check the feed water temperature after economiser.

– Secondary air flow can be reduced but not completely stopped, while there is still combustible material in the gases.

– Primary air for fluidising should be stopped, if the leakage is big. This will stop the burning at once in the bed. Otherwise primary air for fluidising can be kept at minimum flow until all the remaining fuel in the bed has burnt completely, and it helps also to get the rest of the bed ash away from the grid.

– Remove bed material via the ash cooler, if the leakage is entering the bed. Check, that (small amounts of) unburned fuel will not start to burn at the ash conveyors causing a fire.
For smaller leakages follow normal shut down procedures.

- Secondary air flow can be reduced but not completely stopped, while there is still combustible material in the gases.
- Primary air for fluidising can be kept at minimum flow until all the remaining fuel in the bed has burnt completely.
- Remove bed material via the ash cooler, if the leakage is entering the bed.
- Try to determine the approximate location of the leakage by walking round the boiler.
- An economiser leak may be detectable by sound or by an increase in make-up water requirements.
- Note, that water leaks can lead to erosion of adjacent tubes and may cause plugging of ash hoppers and air heaters.
- Steam leaks in superheaters can cause considerable damage to adjacent tubes due to steam cutting.
- Operator judgement must be used to assess the seriousness of the failure and to decide whether an emergency or normal shut down should be performed.
- Monitor the leakage rate and cooling down rate.

5.5.3 Power failure

When a power failure occurs, the boiler shuts down. Most important devices to control the boiler to secured situation are secured by the emergency electricity supply.

6 ASSOCIATED SYSTEMS

Feed water system  S1 LA__.MFB1001
HP –preheater system S1 LAD_.MFB1001
Boiler water system  S1 HA__.MFB0001
Superheaters       S1 HAH_.MFB0001
Reheaters          S1 HAJ__.MFB0001
Blow down system   S1 HAN__.MFB0001
Drains and vents   S1 HAN__.MFB0002 / 0003
Sootblowing system S1 HCB_.MFB0001
HP-steam system    S1 LB__.MFB1001
Sampling           S1 QU__.MFB1001
Flue gas (side temperatures)  S1 HN__.MFB0001
### 7 STEAM QUALITY REQUIREMENTS

**Saturated Steam to Superheater**

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Drum Pressure bar</th>
<th>w/o Turbine</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water Quality</strong></td>
<td>≤ 40</td>
<td>&gt; 40</td>
<td></td>
</tr>
<tr>
<td>Total Iron Fe</td>
<td>0.02</td>
<td>0.02</td>
<td>W</td>
</tr>
<tr>
<td>Total Copper Cu</td>
<td>0.01</td>
<td>0.003</td>
<td>M</td>
</tr>
<tr>
<td>Silicate SiO$_2$</td>
<td>0.02</td>
<td>0.02 *</td>
<td>D</td>
</tr>
<tr>
<td>Sodium + Potassium Na</td>
<td>0.02</td>
<td>0.01</td>
<td>0.01</td>
</tr>
</tbody>
</table>

*Should a turbine experience problems with silicate, it is recommended to reduce boiler water and steam SiO$_2$ concentrations to half of the above mentioned values.*

**Time**

- M = monthly,  
- W = weekly,  
- D = daily
<table>
<thead>
<tr>
<th>Analysis</th>
<th>Reason</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High SiO₂</strong></td>
<td>A. Boiler water SiO₂ high</td>
<td>- increase boiler blow down</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- reduce boiler pressure to equivalent SiO₂ value</td>
</tr>
<tr>
<td></td>
<td>B. Desuperheating control</td>
<td>- by-pass turbine</td>
</tr>
<tr>
<td></td>
<td>- spray water</td>
<td>- shut-down the boiler or equipment and repair to reduce spray water</td>
</tr>
<tr>
<td></td>
<td>- heat exchanger in boiler</td>
<td>dissolved solids</td>
</tr>
<tr>
<td></td>
<td>drum is leaking</td>
<td>- investigate cause of foaming</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and correct</td>
</tr>
<tr>
<td></td>
<td>Leads to scaling in turbine</td>
<td>- see above &quot;high SiO₂&quot;</td>
</tr>
<tr>
<td></td>
<td>and superheaters</td>
<td>- if this is not a result of foaming, improve the boiler construction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(mist elimination and steam drying)</td>
</tr>
<tr>
<td><strong>High suspended solids</strong></td>
<td>A. Foaming in boiler</td>
<td>- too high specific load in part of superheating surface. The cause</td>
</tr>
<tr>
<td></td>
<td></td>
<td>can be removed by altering boiler construction and reducing specific</td>
</tr>
<tr>
<td></td>
<td></td>
<td>load.</td>
</tr>
<tr>
<td></td>
<td>B. Too much moisture in saturated</td>
<td>- reduce boiler water dissolved solids</td>
</tr>
<tr>
<td></td>
<td>steam</td>
<td>- increase boiler water quality requirements</td>
</tr>
<tr>
<td></td>
<td>C. Desuperheating control</td>
<td></td>
</tr>
<tr>
<td></td>
<td>D. &quot;Hide-out&quot; of salts</td>
<td></td>
</tr>
</tbody>
</table>