**Project:**

**MULTI FUEL CFB BOILER SIMULATOR**

<table>
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<tr>
<th>Author</th>
<th>Approved</th>
<th>Language</th>
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<tr>
<td>JJA</td>
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**Document title:**

**SYSTEM DESCRIPTION**

**FEED WATER SYSTEM**

<table>
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<th>Submitted for</th>
<th>Customer reference</th>
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1 GENERAL

The function of the feed water system is to provide feed water to the boiler in all operation conditions with appropriate quality, temperature and pressure.

The function of the feed water tank deaerator is to remove oxygen and other non-condensable gases from the condensate and make-up water entering the feed water system in order to prevent corrosion. The protection of the feed water piping and the boiler heating surfaces is also improved with the chemical dosing to the feed water tank. In the water-steam circulation chemicals are used for oxygen prevention and pH control. Feed water system is shown in diagram S1LA__-MFB1001__.

The feed water system consists of a feed water tank equipped with a deaerator (Stork type sprayer deaerator; built-up with the feed water tank) and two high pressure feed water pumps.

The water required by the feed water system is taken from the feed water tank. Tank volume is 200 m³, which capacity is sufficient for 24 minutes at BMCR (Boiler Maximum Continuous Rate). The design basis for the feed water tank effective volume is that there is always enough feed water in the tank for safety shutdown of the plant in all operation situations. Feed water tank receives water from the following systems and equipment (partly collected together already in piping):
- Steam turbine condenser (main condensate + make-up water)
- Low pressure preheaters
- High pressure preheaters
- Steam coil air heaters condensate tank
- Make-up water (start-up / emergency)

In normal operation make-up water is led to the condenser to improve efficiency. Feeding make-up water into the steam turbine condenser normally controls the water level in the feed water tank. Mixed steam turbine condensate and make-up water is preheated in three stages before entering the feed water tank. Make-up water is led directly to the feed water tank during start-up and if the water level in the feed water tank goes below the low limit.

The upper level of the tank is controlled by the overflow valve S1 LAA10 AA101, which opens if the maximum water level in the tank is reached and closes (with a delay) when the water level has lowered below the maximum allowable level. The overflow is led to the boiler blow down tank.

Condensate from the steam coil air heaters condensate tank is pumped to the main condensate line after low pressure preheaters.

Condensates from high pressure preheaters are led directly to the feed water tank. Flash steam from the boiler continuous blow down tank is led to the feed water tank degassing steam line.
Feed water tank is connected to steam turbine extraction 4 and the tank pressure is sliding according to steam turbine load (2 bar(g)…4.8 bar(g)). If the turbine extraction 4 pressure slides below 2 bar(g), steam to feed water tank is taken via reduction valve S1LBC30AA201 from cold reheat. Set pressure for pressure reduction valve is 2 bar(g).

Degassing steam line is led to the bottom of the tank in order to remove residual oxygen from the feed water tank and to heat up feed water.

During start-up (steam turbine and main boiler not in operation) steam to feed water tank is taken from the auxiliary steam header.

At the beginning of start-up steam to auxiliary steam header is taken from auxiliary boiler. Auxiliary boiler steam capacity is 4 kg/s. The auxiliary boiler has its own feed water system (tank, pump etc.) After main boiler start up, and steam pressure in cold reheat is adequate, steam to auxiliary header is taken from cold reheat via pressure reduction valve S1LBC30AA201.

Steam parameters at the header are kept at 3 bar(g)/230 °C during start-up.

Feed water pumps are dimensioned so, that the maximum steam capacity of the boiler can be reached with one pump (see design data). During normal operation one pump is running and the other is stand-by.

Feed water pump's rotation speed is controlled by a variable speed coupling, which receives the control impulse from the pressure difference value over feed water control valve. The feed water control valve regulates the water level in the drum.

Spray water to HP-bypass stations is taken from feed water line before high pressure preheaters. Spray water to superheater and reheater temperature control is taken from feed water line after high pressure preheaters.

From feed water pump extraction spray water is taken to auxiliary steam reduction station S1 LBC40 AA201.
2  DESIGN DATA

As a design basis for the feed water system are the following feed water flows:

- Boiler 113.0
- Spray water 0
  - HP-bypass reduction station 0
  - Auxiliary steam reduction station 0.5

Maximum flow to HP-bypass stations is 12.2 kg/s. Maximum capacity of pump extraction is 4.5 kg/s.

3  EQUIPMENT DATA

3.1  Feed water tank
KKS Code S1 LAA10 BB501.

Feed water tank capacity is sufficient for 24 minutes feed water demand at BMCR.

The feed water tank shall be located at the level +56.750 and the feed water pumps are at the level +36.750. The pressure level of the feed water tank is sliding between 2.0…4.8 bar(a) during normal operation.

Feed water tank and deaerator design values are:

- Volume (gross) 200 m$^3$
- Volume (effective) 176 m$^3$
- Diameter 4000 mm
- Total length 17100 mm
- Design pressure +8.0 bar(g)
- Design pressure -1.0 bar(g) (full vacuum)
- Design temperature (tank) 320 °C
- Design temperature (steam inlet) 430 °C
- Operating pressure 2…4.8 bar (g)
- Operating temperature 134…158 °C
- Material, shell and heads P235GH
- Corrosion allowance (CS) 1 mm
- Distance between supports 13000 mm
The design values of the deaerator (built-up with the feed water tank) are as follows:

- Design pressure: +8.0 bar (g)
- Design pressure: -1.0 bar (g) (full vacuum)
- Design temperature: 320 °C
- Material, sprayer material: Stainless steel

The design values of the sprayer are as follows:

- Sprayer maximum capacity: 120 kg/s
- Pressure drop: 0.6 bar (at the max. capacity)
- Drawing No. (of manufacturer): 11897

Feed water tank and deaerator are dimensioned according to the following operation points:

<table>
<thead>
<tr>
<th>Norm. operation</th>
<th>min</th>
<th>max</th>
<th>start-up</th>
<th>turbine trip</th>
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<tbody>
<tr>
<td>Main condensate flow *)</td>
<td>kg/s</td>
<td>35.7</td>
<td>86.6</td>
<td>79.6</td>
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<tr>
<td>Main condensate temperature</td>
<td>°C</td>
<td>94</td>
<td>115</td>
<td>23</td>
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<tr>
<td>HP preheater condensate flow</td>
<td>kg/s</td>
<td>4.3</td>
<td>17.9</td>
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<tr>
<td>HP preheater condensate temperature</td>
<td>°C</td>
<td>147</td>
<td>170</td>
<td></td>
</tr>
<tr>
<td>Other condensate flow</td>
<td>kg/s</td>
<td>1.5</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>Other condensate temperature</td>
<td>°C</td>
<td>102</td>
<td>102</td>
<td></td>
</tr>
<tr>
<td>Make-up water flow</td>
<td>kg/s</td>
<td>0.8</td>
<td>2.2</td>
<td>22.5</td>
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<tr>
<td>Make-up water temp. before preheating</td>
<td>°C</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Make-up water temp. after preheating</td>
<td>°C</td>
<td>94</td>
<td>115</td>
<td>20</td>
</tr>
<tr>
<td>Degassing steam temperature</td>
<td>°C</td>
<td>255</td>
<td>311</td>
<td>230</td>
</tr>
<tr>
<td>Degassing temperature</td>
<td>°C</td>
<td>133</td>
<td>158</td>
<td>120</td>
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<tr>
<td>Degassing steam pressure</td>
<td>bar (g)</td>
<td>2</td>
<td>4.8</td>
<td>1</td>
</tr>
</tbody>
</table>

*) Make-up water flow is not included to main condensate flow

Feed water oxygen content at feed water tank outlet is < 10 ppb
3.2 **Feed water pumps**

KKS Code S1 LAC10 AP101 and S1 LAC20 AP101.

Feed water pumps are designed according to TRD 401 regulations. Normally one pump is running and other is stand-by.

According to TRD rules 1.25 x maximum total flow (boiler maximum capacity + reduction valves spray water) with maximum operation pressure at boiler outlet (HP by-pass station set pressure) has to be reached with one pump. Also 1.1 x maximum operation pressure at boiler outlet with maximum total flow has to be reached with one pump.

Calculated spray water to HP-bypass reduction stations is 12.2 kg/s and to auxiliary steam reduction station 4.5 kg/s. Feed water pumps are hydraulic gear driven. Normal operation range is 3192… 4209 r/min.

Feed water pump technical data:
- Number of pumps: 2 x 100 %
- Manufacturer: KSB
- Type of pump: HGC 5/8

<table>
<thead>
<tr>
<th>TRD dimension points</th>
<th>Operation points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.1 x max. pressure</td>
</tr>
<tr>
<td>Flow (discharge), kg/s</td>
<td>125.4</td>
</tr>
<tr>
<td>Flow (extraction), kg/s</td>
<td>4.5</td>
</tr>
<tr>
<td>Feed water temperature, °C</td>
<td>158</td>
</tr>
<tr>
<td>Head, m</td>
<td>2568</td>
</tr>
<tr>
<td>Rotation speed, r/min</td>
<td>4099</td>
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<tr>
<td>Extraction pressure, bar(g)</td>
<td>29.4</td>
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<tr>
<td>Shaft power demand, kW</td>
<td>3904</td>
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<tr>
<td>NPSHr m</td>
<td>10.4</td>
</tr>
<tr>
<td>NPSHa m</td>
<td>16.8</td>
</tr>
</tbody>
</table>

Feed water pump operation and cooling in low load situations is secured by leading feed water back to feed water tank via minimum flow valve.

Variable speed coupling technical data:
- Manufacturer: Voith
- Type of coupling: R 17 K 400 M
- Weight: 5500 kg
- Losses at pump max. operation: 270 kW
- Minimum slip: 3.7 %
3.3 **Feed water line**

Design values of the feed water line (S1 LAB30 BR010) are the following:
- Design pressure          355 bar
- Design temperature      200 °C
- Nominal diameter         DN250
- Do x s                   273 x 28 mm
- Material                 15NiCuMoNb5

3.4 **Feed water tank safety valve**

KKS Code S1 LAA15 AA401.

Design basis of feed water tank safety valve is the maximum flow of one main condensate pump (over flow valve S1 LAA10 AA101 failure) and maximum steam flow from HP1 pre-heater (HP preheater condensate control valve S1 LCH30 AA201 failure). These situations are not simultaneous.

Feed water tank safety valve technical data:
- Capacity
  - Steam, 280 °C          17 kg/s
  - Saturated water        65 kg/s
- Set pressure            8.0 bar(g)
4 AUTOMATION AND INSTRUMENTATION

4.1 Feed water pumps

The feed water pumps are equipped with change-over automatic. The stand by pump will automatically start if the operating pump trips.

Feed water pump’s rotation speed is controlled by a variable speed coupling, which receives the control impulse from the pressure difference value over feed water control valve. The feed water control valve regulates the water level in the drum.

4.2 Main condensate flow measurement

Main condensate flow before feed water tank is measured and the measurement is compensated with condensate temperature.

4.3 Feed water tank steam flow measurement

Steam flow before feed water tank is measured and the measurement is compensated with steam pressure temperature.

4.4 Feed water tank level control

Feed water tank level measurement normally controls make-up valve S1 GHC40 AA201, which regulates make-up water flow to condenser.

Make-up water is pumped directly to the feed water if the water level in the feed water tank goes below the low limit.
5 SYSTEM OPERATION

5.1 Start-up

The start-up of the feed water system begins with the feed water tank filling. Emergency make-up water pump S1 GHC40 AP101 is used to supply water to the feed water tank until normal water level has been reached. Heating and gas removing steam is led to the bottom of the tank at the same time with water filling. Water level must be over steam rake (low water limit) before leading steam to the tank.

At the beginning of start-up steam to auxiliary steam header is taken from auxiliary boiler. Auxiliary boiler steam capacity is 4 kg/s and steam data 3 bar(g) / 230 °C. Feed water is heated to approximately 120 °C with the control valve S1 LBG50 AA201 (from the auxiliary steam header). The feed water pipes are filled by opening the required shut-off valves after the feed water has reached the proper temperature.

After main boiler start up and steam pressure in cold reheat is adequate, steam to auxiliary header is taken from cold reheat via pressure reduction valve S1LBC40 AA201. In this situation steam to feed water tank heating can be also taken straight from the cold reheat with the reduction valve S1LBC30 AA201.

A feed water pump is ready to be started after the system has been filled with water. When the pump is started manually, the procedure is the following (no pressure in the feed water line, shut-off valve closed):

1. Minimum circulation line S1 LAB11/21 BR010 must be always open. The venting of the feed water line, the economizer and the drum must be open according to boiler start-up instructions.
2. The selected feed water pump is started on minimum rotation speed and the discharge pressure is raised to about 35 bar.
3. The by-pass line valve (S1 LAB12/22 AA101) of the discharge side of the main shut-off valve is opened.
4. Main shut-off valve (S1 LAB10/20 AA101) can be opened, when the feed water pressure after the valve is over minimum pressure demand by the pump manufacturer, which is > 30 bar (water pressure straight after pump). The main valve by-pass will be closed.
5. The vents of the boiler must be closed according to boiler start-up instructions.
6. Level controls of the drum and the pressure difference control of the feed water control valve must be put to automatic mode.
7. The other feed water pump can be put on stand-by operation by selecting automatic change over automatic to auto mode. Then the change over automatic opens the main shut-off valve of the stand-by pump and checks that all starting requirements are fulfilled. The precondition for the function of the change over automatic is that the boiler is in operation.
5.2 Normal operation

The plant is normally operated with one feed water pump, while the reserve pump remains stand-by.

Feed water pump controls the pressure difference over the feed water control valve. Pressure difference is adjusted by changing the rotation speed of the pump with variable speed coupling.

If feed water flow decreases below ca. 35 kg/s, the minimum flow valve will automatically S1 LAB20/30 AA301 open.

Boiler drum level is regulated with the feed water control valve and the control signals are drum level, feed water flow and steam flow.

Water level in the feed water tank is kept in set value by leading make-up water to the condenser.

5.3 Disturbances

- Feed water pump stops → the change over system switches automatically the stand-by feed water pump on if there is a failure in the operating pump. The change over system must be activated from the display and the stand-by pump must be in automatic mode (start-up requirements must be fulfilled).

- High pressure difference over suction strainer → too high pressure difference (Δp > 0.5 bar) over feed water pump suction strainer causes alarm. Stand-by pump is started and running pump is stopped. Suction strainer is cleaned.

- Low level in feed water tank → low level limit causes alarm and emergency make-up water pump S1 GHC40 AP101 is started. If low limit 2 is reached, running feed water pump is stopped.

- High level in feed water tank → overflow valve S1 LAA10 AA101 is opened and feed water is led to the boiler blow down tank. Overflow valve closes with delay when the water level has lowered below the maximum allowable level.
6 CONNECTED SYSTEMS

- Blow down P&I-diagram  S1HAN__-MFB0001_
- High pressure steam system  S1LB___-MFB1001_
- Auxiliary steam system  S1LBG__-MFB1001_
- Low pressure preheaters  S1LCC__-MFB1001_
- Make-up water system  S1GHC__-MFB1001_
- SCAH condensate system  S1LCN__-MFB1001_
- Sampling system  S1QU___-MFB1001_
- Chemical dosing  S1QC___-MFB1001_