Handling a serious sea water contamination of the water-steam circuit of a once-through boiler at Amagerværket

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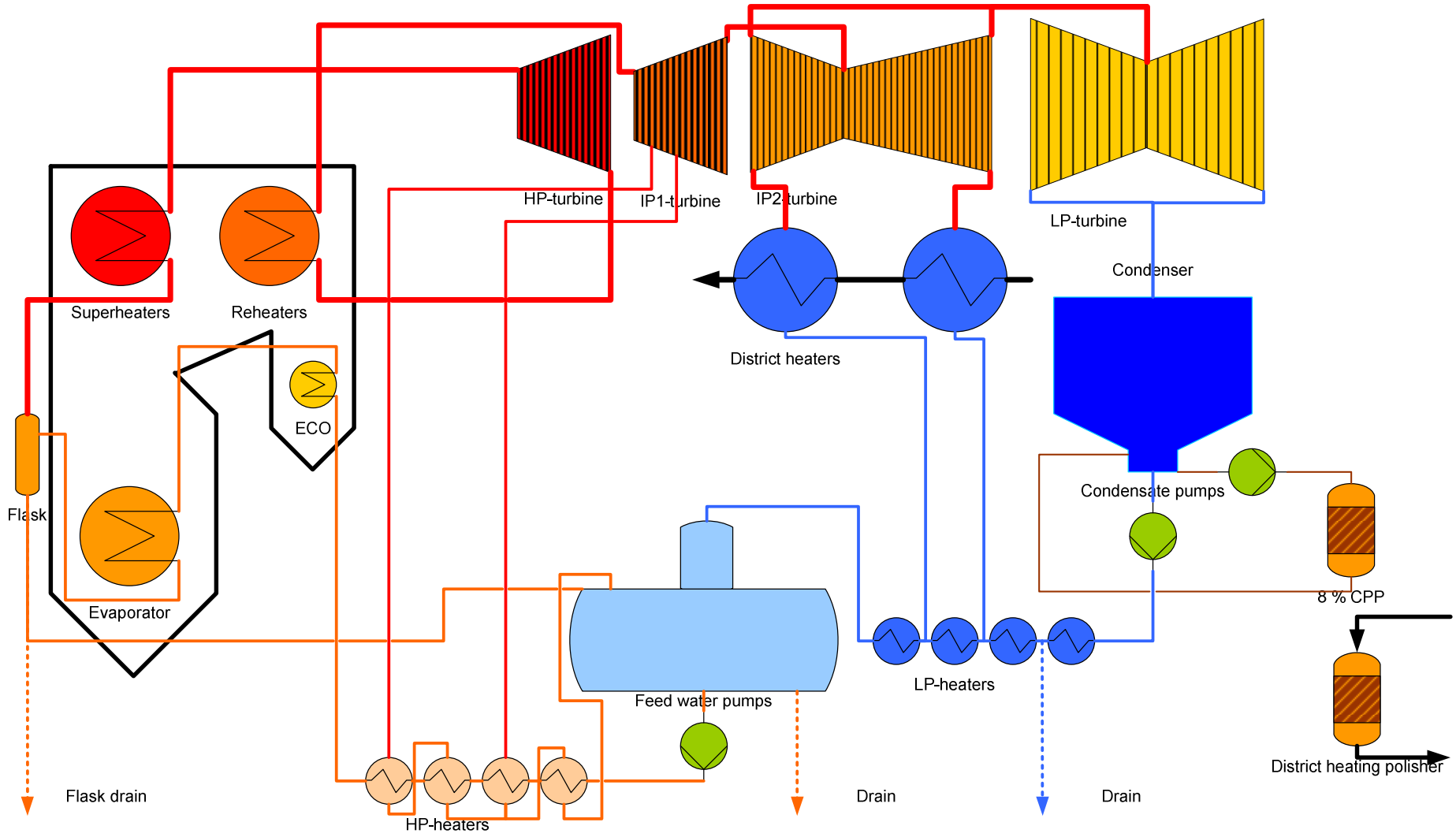
The unit AMV3:
250 MW electricity
330 MJ/s district heating
Commissioned 1989
Once-through boiler
Supplier: Babcock
Turbines: HP, IP1, IP2, LP
Titanium condenser
Sea water cooling
Supplier: BBC/Alstom

Overview of water-steam circuit



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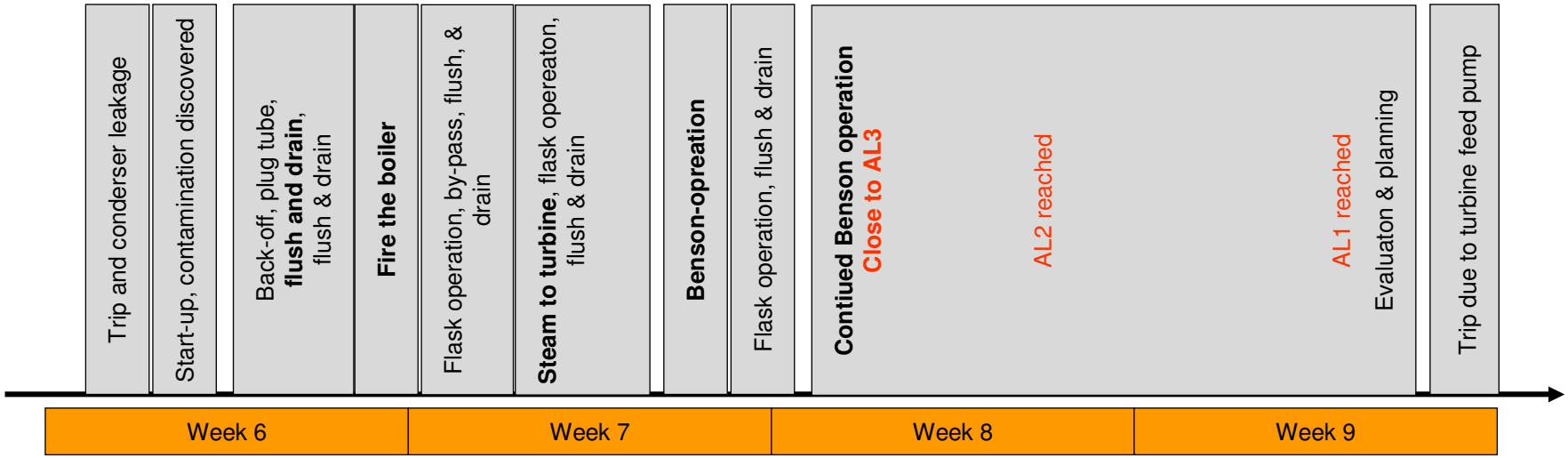
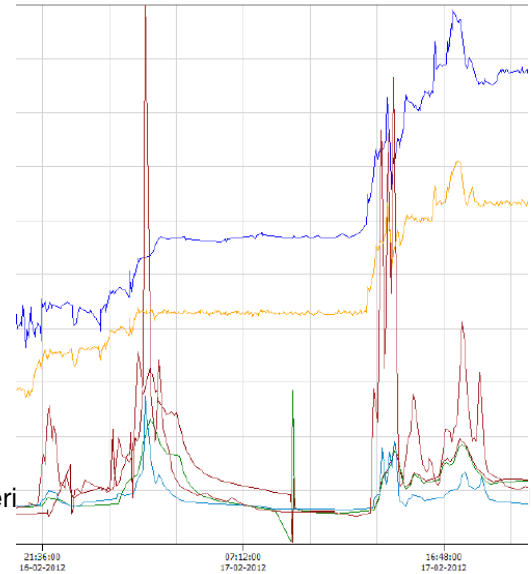
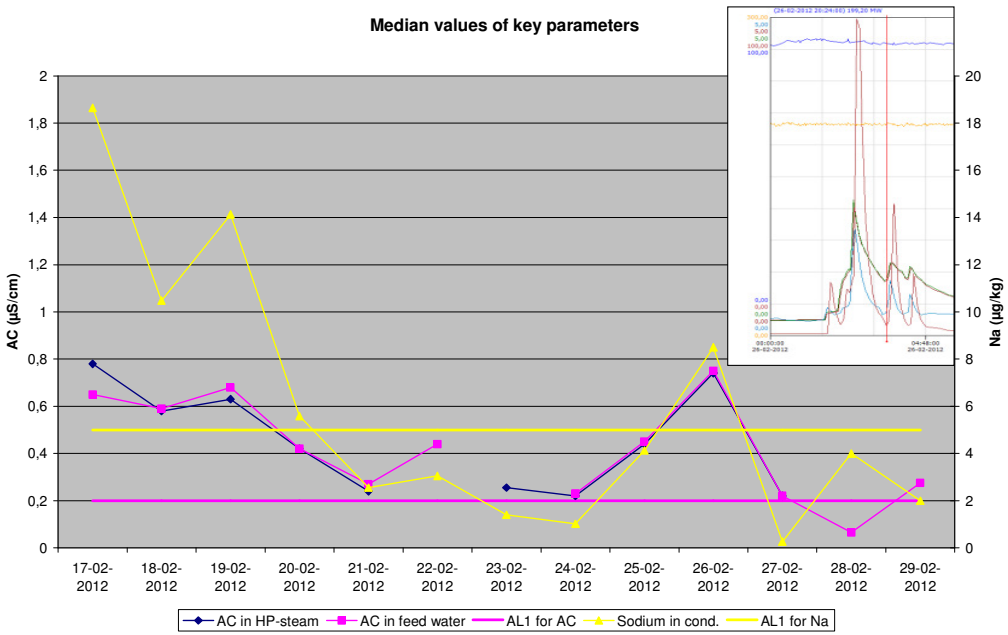
The contamination and immediate actions



AC, feed water: 300 µS/cm 2 µS/cm

AC, steam: 0.3 µS/cm 0.2 µS/cm ~1 µS/cm 0.9 µS/cm 0.5 µS/cm 0.2 µS/cm





Evaluation of the situation, end of February

- The complete water-steam circuit has been seriously contaminated with salt
- Corrosion risk of components:
  - Low at continued operation
  - High at next outage:
    - Prepare for thorough dry conservation, expect stop at any time!
- Possibilities to clean up
  - Acid cleaning – time consuming and costly – necessary, if salts deep into oxide layer?
  - Flush superheaters with feed water – linear flow rate 0.5 m/s? – ad hoc drain possibilities?
  - **Wash superheaters with wet steam** – limited experience, but some – control of spray water to get saturation?
  - Wash of turbines by water-filling – not applicable to all turbines – not to all parts
  - Foam wash – promising, but only applicable to HP-turbine
  - **Wash of turbines with wet steam** – possible for all turbines – all parts in contact with steam reachable

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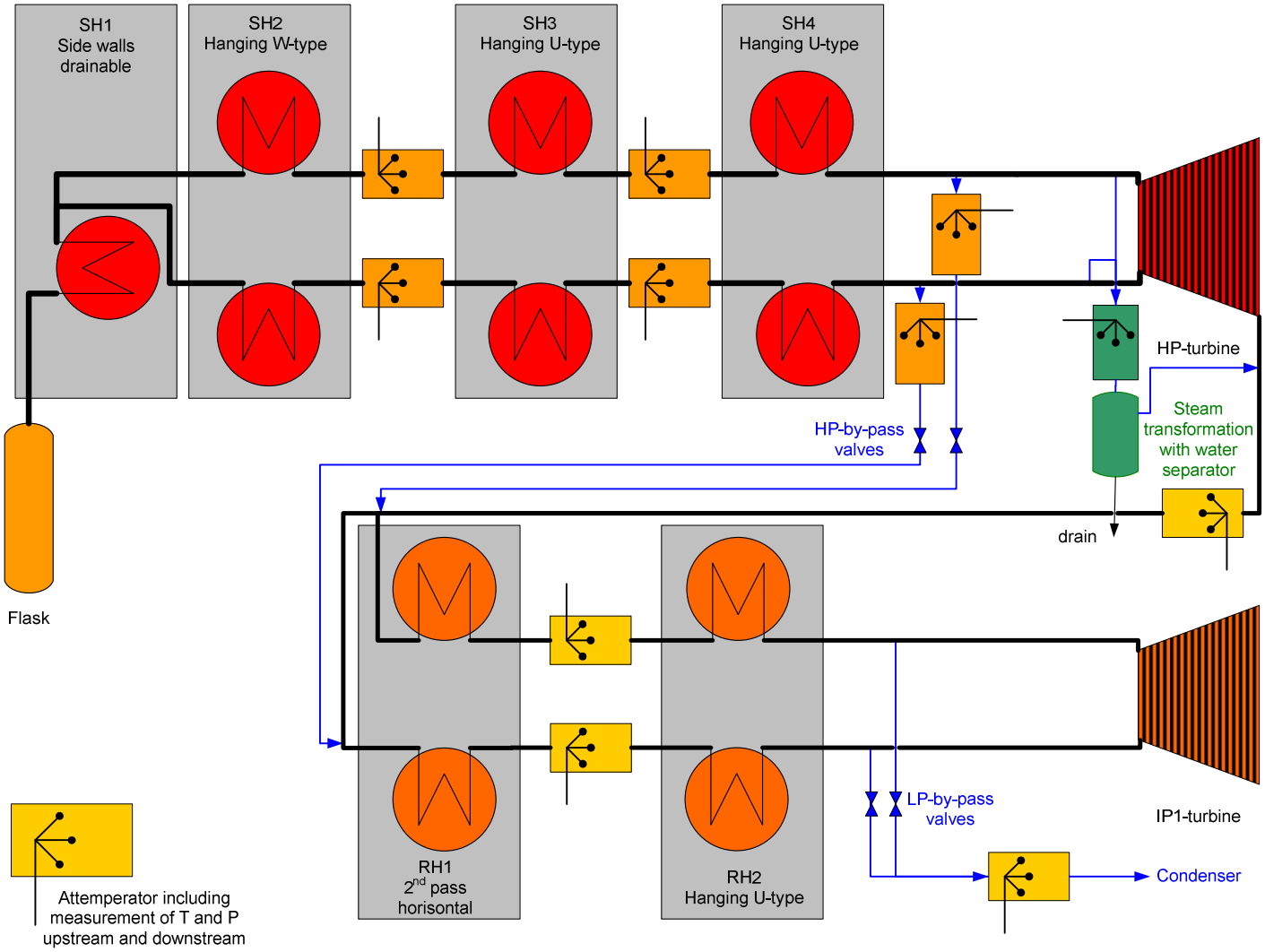
Overview of superheaters and attemperators



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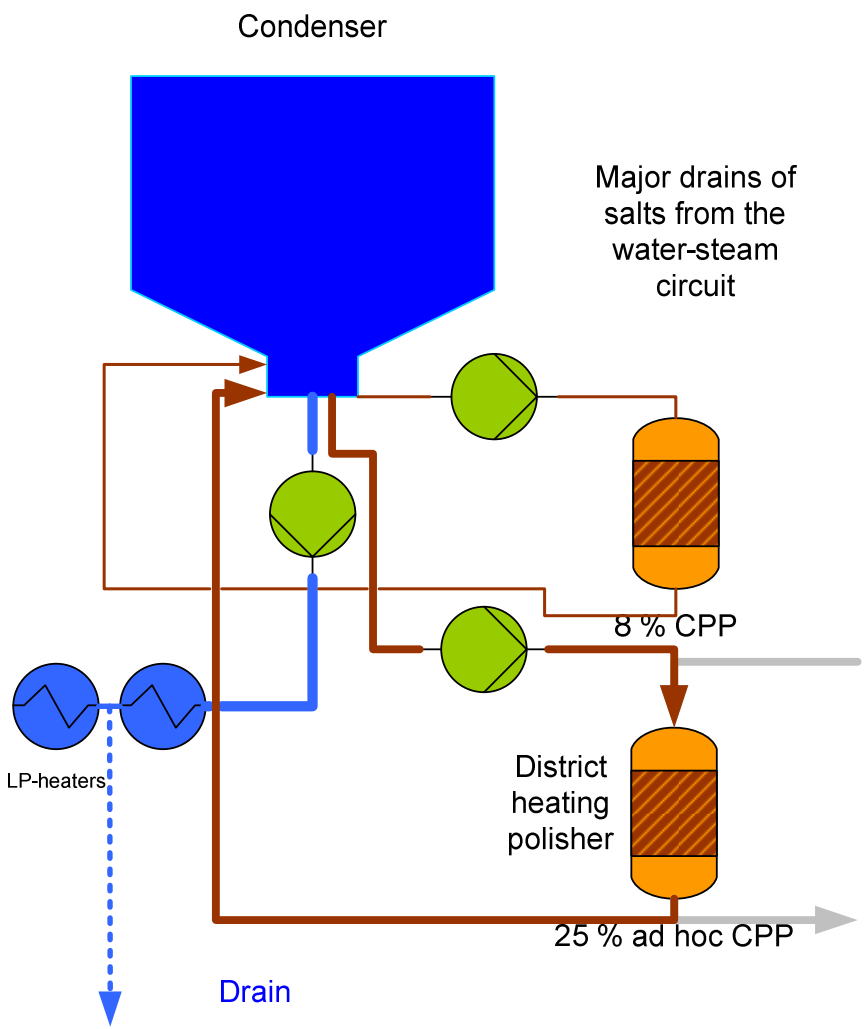
Monitoring and temporary arrangements

Sample point	SC on-line	AC on-line	Na on-line
Flask drain		Ad hoc	
Feed water	Stationary	Stationary	
HP-steam		Stationary	
Hot RH-steam		Stationary	Ad hoc
Condensate after cond. pumps		Stationary	Stationary
Condensate to CPP	Ad hoc & stationary	Ad hoc	(Ad hoc)
Rinsed condensate after both CPP's	Stationary		
Drain from HP-heater 60 and 70		Ad hoc	
Drain from steam transforming system		Ad hoc	



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Procedure for wet steam wash of superheaters

- Flush & drain feed water tank and evaporator until AC 1 µS/cm is reached – condition to 2 mg/kg NH_3 (pH 9.6) and heat feed water to 60-80 °C
- Fill SH1 with feed water through flask exit. Empty through flask drain
- Fire the boiler, 2-3 oil burners i lowest gallery, ~10 kg/s (~8 %) steam production, by-pass operation, ~40 bar HP-steam – i.e. lowest stable operation of boiler
- Wash HP-superheaters 3 and 4 (stationary conditions)
  - Increase spray water flow in HP-attemperators until saturation
  - Watch Na and AC in condensate and steam
  - Dry superheaters out
  - Repeat until salts in condensate falls off.
- Wash RH-superheater 1 and 2 (transient conditions)
  - Saturate HP-steam
  - Build up max. pressure in HP-system by throttling HP-by-pass
  - Keep pressure in RH-system above min. pressure for spraying in HP-by-pass (16 bar)
  - Increase spray water in HP-by-pass and RH-attemperator to near saturation
  - Open HP-by-pass as fast as possible. Pressure transient will saturate steam in reheaters
  - Watch Na and AC in condensate and steam
  - Repeat until salts in condensate falls off
  - Dry reheaters out

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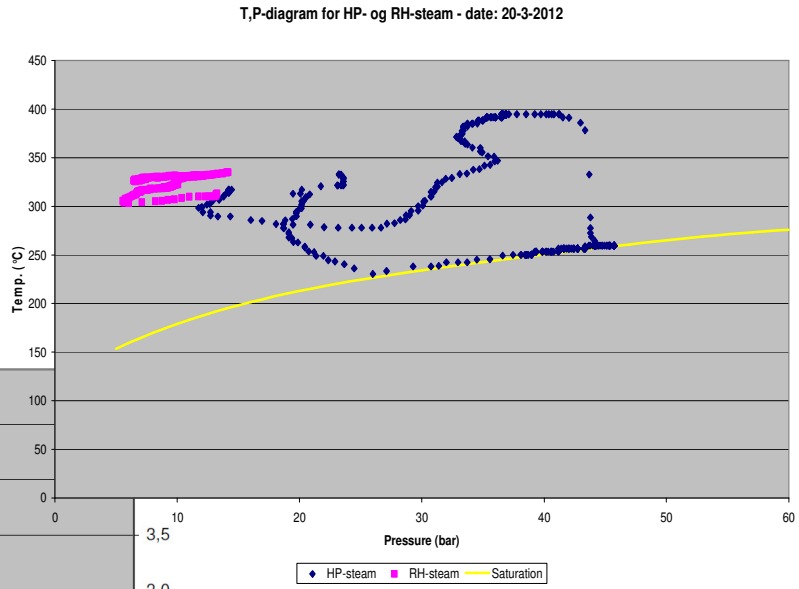
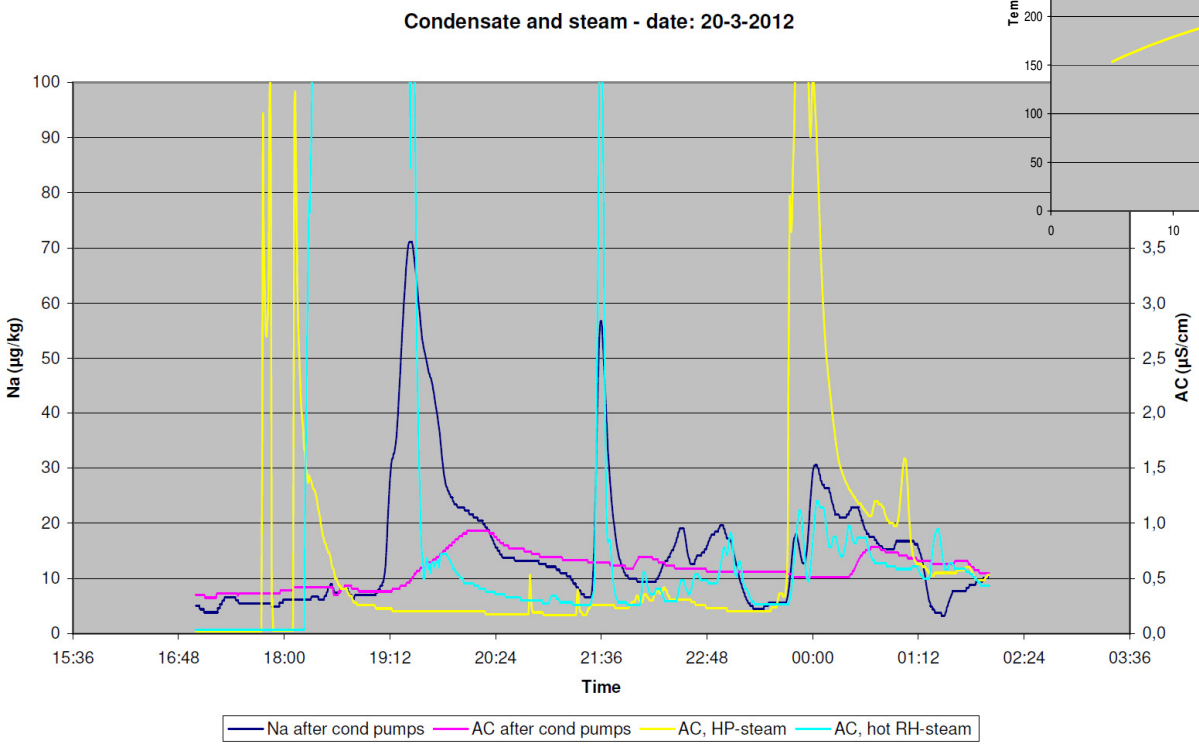
Wash of superheaters with wet steam

Traces of T and P from 20-3-2012 22:00 to 21-3-2012 01:15.

Saturation of superheaters is maintanied for 1½ hour from 23:30.





On-line measureement in steam and condensate

The first two sets of peaks are due to start-up of the boiler

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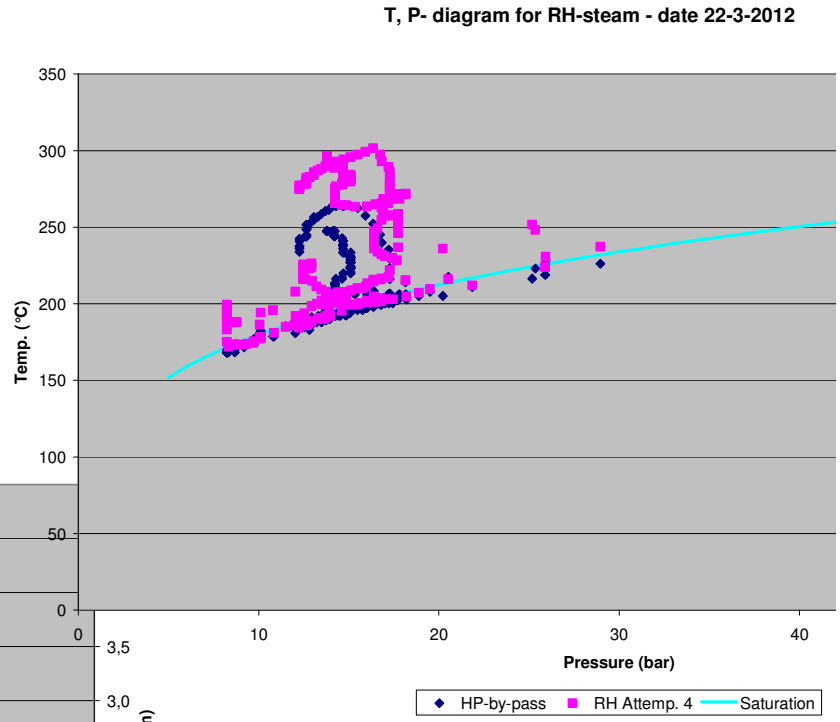
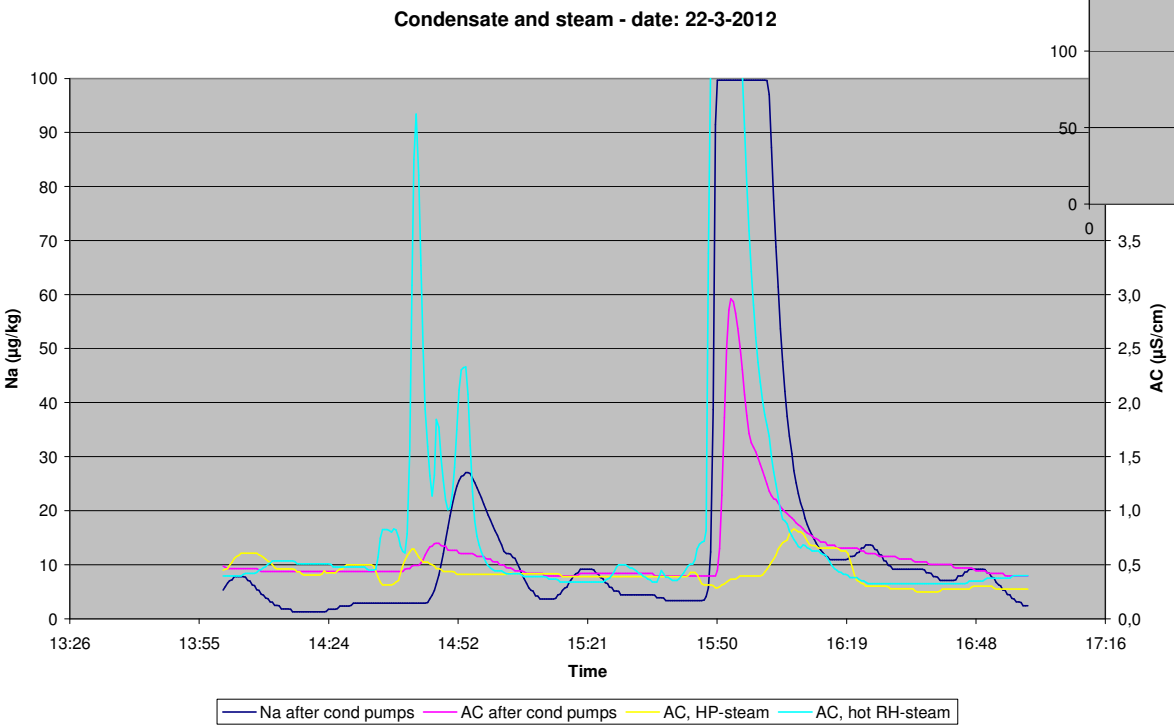
Wash of reheaters with wet steam

Traces of T and P from 22-3-2012 14:00 to 17:00.

Saturation of reheaters is maintanied for 5-15 min per gradient.





Peak values during transients	Na in hot RH-steam (µg/kg)
22-3-2012 13:08	282
22-3-2012 14:38	450
22-3-2012 16:00	9900
23-3-2012 10:05	458
23-3-2012 10:20	197
23-3-2012 13:42	129

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Procedure for wet wash of turbines

- Establish saturated steam conditions for HP- ((P,T) = (35 bar, 242 °C)) and RH-steam ((P,T) = (26 bar, 226 °C)) at turbine inlet. Await stable conditions for 15 min, check steam quality (AL2 level).
- Check that turbine drains are all open. Monitor vibrations, differential expansion, valve positions, rotor temp., etc.
- Wash of HP-turbine
  - Adjust target speed to 600 rpm and ratio between turbine valves to allow for max. HP-steam relative to IP-steam (min. K-factor).
  - Run the turbine up to 600 rpm, check saturation upstream blading (T, P).
  - Wash HP-turbine for 30 min., monitor AC and Na in condensate – then reset. Repeat until AC and Na in condensate drops off.
- Wash of IP-turbine
  - Adjust target speed to 600 rpm and ratio between turbine valves to allow for min. HP-steam relative to IP-steam (max. K-factor).
  - Run the turbine up to 600 rpm, adjust K-faktor to min., monitor AC and Na in condensate – then reset, and let turbine roll down to 100 rpm
  - Repeat acceleration between 100 and 600 rpm – saturation in IP-turbine occurs only during this short period (~20 s).
  - Repeat until AC and Na in condensate drops off.

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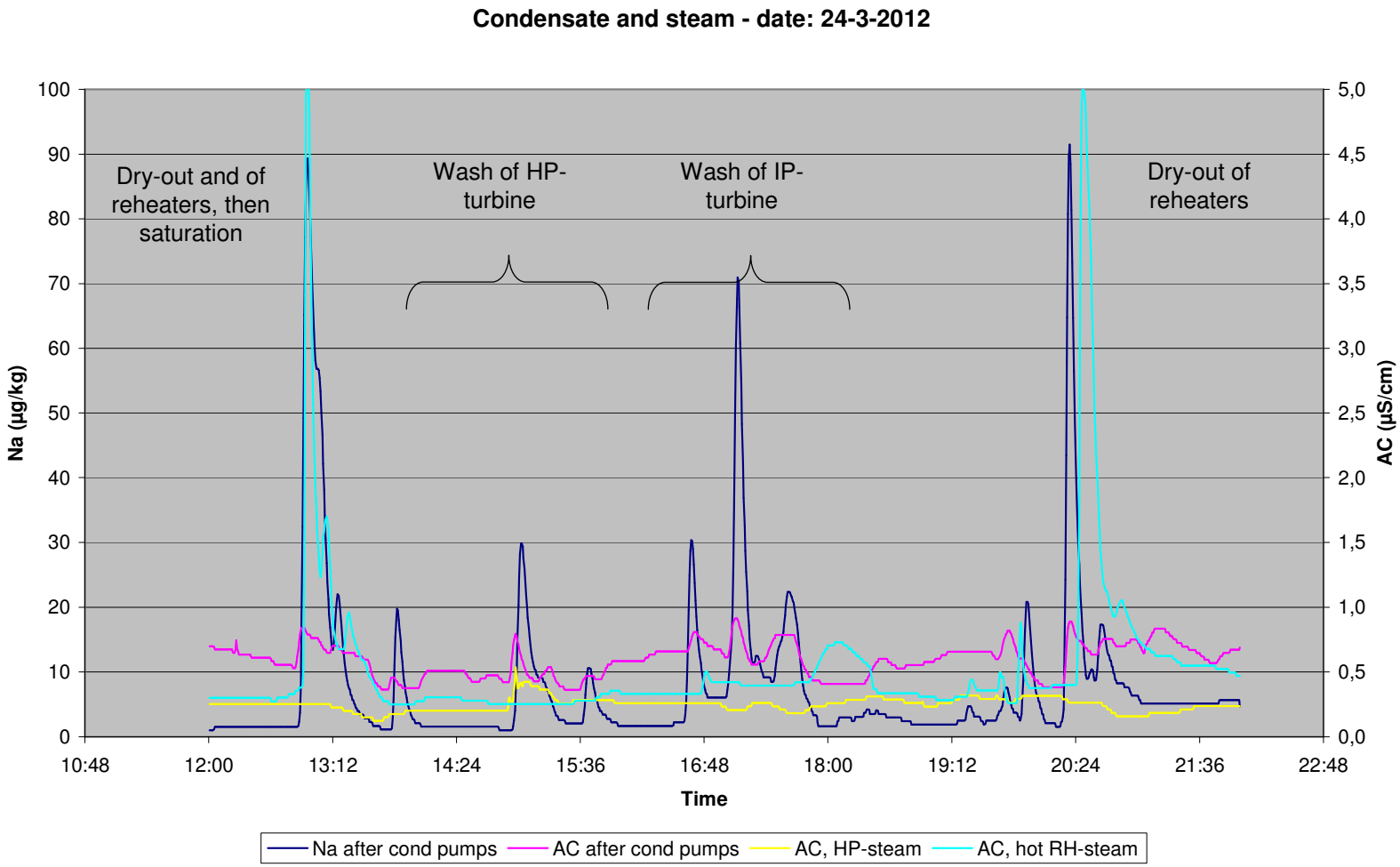
Wash of HP- and IP-turbines



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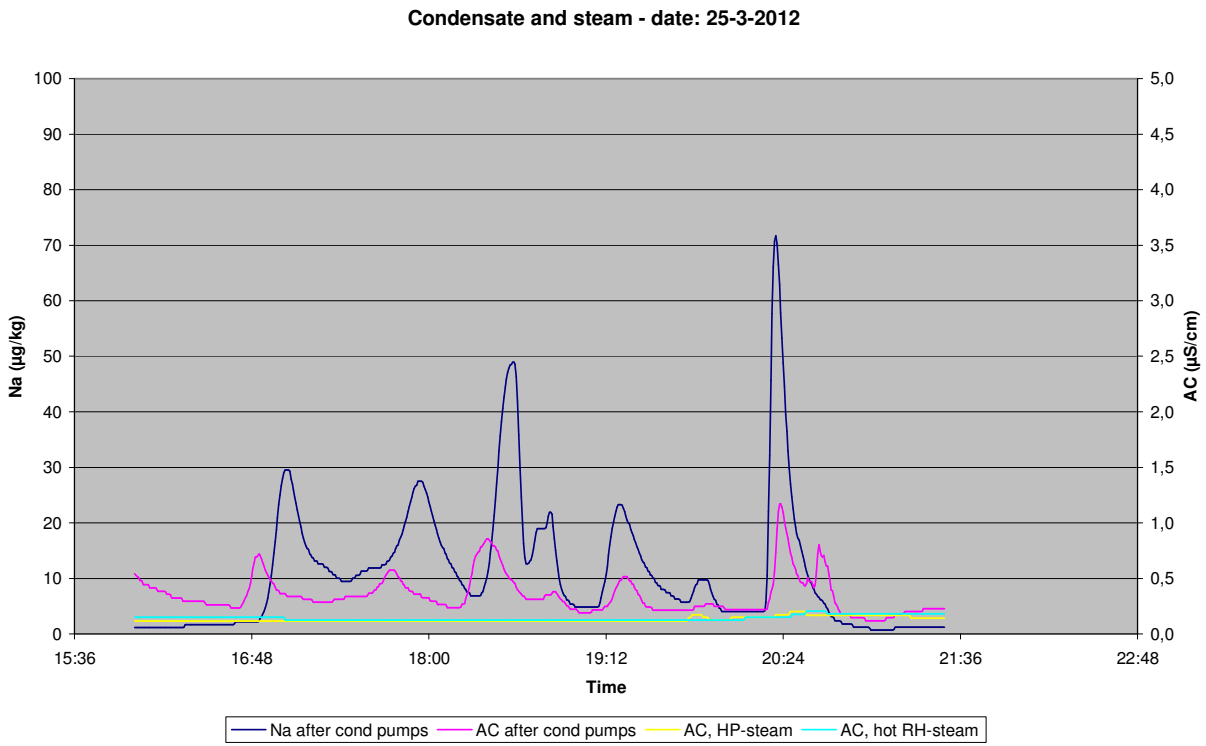
Wash of HP-heaters and district heaters

- Procedure
  - Run the boiler at low load (~25 %) with steam supply to HP-heaters and district heaters.
  - For each heater, one at a time:
    - Direct condensate to condenser/drain.
    - Cut steam supply for 10-15 min to allow cooling of materials.
    - Admit steam again. Steam condenses at cool surfaces and washes salts to drain.



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Conclusions

- Analysis of many grab samples of condensate at more sample points has shown the presence of:
  - Na^+, K^+, Ca^{++}, Mg^{++}
  - Cl^-, SO_4^{--}, NO_3^-, and even PO_4^{---} in large quantities
- The charge balance between cations and anions indicates that 30-50 % of the cations are associated with OH^- or CO_3^{--} in the salts.
- A rough estimate based on Na- and AC-measurements in the condensate, steam production and flow to CPP's shows these amounts:

Component	Based on Na-measurement (NaCl/g)	Based on AC-measurement (eq. NaCl/g)
Super- and reheaters	150	360
Turbines	10	40
HP-heaters and district heaters	100	130
Totals	**260**	**530**

- The contamination of the water-steam circuit of AMV3 was handled by:
  - Preparing for immediate dry conservation at next stop to avoid rapid corrosion
  - Planning of measures to clean up the system at next stop – wet steam wash was selected from technical, time, and economical reasons.
  - Although technical difficulties, superheaters, reheaters, and subsequently the turbine were washed in ~2 weeks removing considerable amounts of salts.
  - The corrosion risk has been reduced, however since the clean up is not complete, there must still be focus on conservation during outage.
  - Evaluation of the complete story has let to:
    - Recommendations on improved chemistry monitoring (shortening response time)
    - More focus on water chemistry (action level thinking and education)

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